N.I.

Internal Note No. 68-FM-302

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 68-FM-302

December 12, 1968

REVISION 1 TO THE ATTITUDE SEQUENCE FOR THE APOLLO 8 SPACECRAFT OPERATIONAL TRAJECTORY

Lunar Mission Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

MSC INTERNAL NOTE NO. 68-FM-302

PROJECT APOLLO

REVISION 1 TO THE ATTITUDE SEQUENCE FOR THE APOLLO 8 SPACECRAFT OPERATIONAL TRAJECTORY

By Mission Design Section
TRW Systems Group

December 12, 1968

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

MSC Task Monitors
H. D. Beck
R. D. Duncan

Approved: for Ronald L. Berry, Chief
Lunar Mission Analysis Branch

Approved: John P. Mayer, Chief
Mission Planning and Analysis Division

CONTENTS

TABLES

FIGURES

REVISION 1 TO THE ATTITUDE SEQUENCE FOR THE APOLLO 8 SPACECRAFT OPERATIONAL TRAJECTORY

By Mission Design Section
TRW Systems Group

1. SUMMARY AND INTRODUCTION

1.1 General

This document presents the updated operational attitude sequence for the Apollo 8 lunar orbit mission. This update is necessitated by recent changes in the mission profile and spacecraft attitude requirements. The spacecraft attitude data and event sequence contained in this report reflect the latest philosophy related to the development of the mission attitude timeline. Consequently, the original attitude sequence for the Apollo 8 Spacecraft Operational Trajectory, Reference 1, is superseded as the spacecraft attitude data source by this document.

The spacecraft operational attitude data are presented in the following format:

1. Discussion of the major attitude events occurring during the mission

2. Figures illustrating the attitude events

3. Mission attitude timeline indicating the chronological sequence of events (Table I). Event times for the mission were obtained from the Apollo 8 Final Flight Plan, Reference 2.

4. Tabular data summarizing the pertinent parameters of interest (Table II)

1.2 Trajectory Profile

The spacecraft operational trajectory furnishing the state vector and ephemeris data for generating the required attitude data was obtained from the Lunar Mission Analysis Branch of MPAD-MSC. The trajectory was precision integrated on the Apollo Reference Mission Program Version ARM06. Launch date for the trajectory was 21 December 1968 with a launch azimuth of 72 degrees.

Major events in the mission include the launch to insertion into a 100-nautical mile altitude earth parking orbit. A Pacific injection on the second revolution in earth orbit initiates the translunar phase of the mission. The translunar and transearth phases are characterized by relatively short flight times of approximately 66 hours and 57 hours, respectively. The lunar orbit phase consists of ten revolutions in lunar orbit devoted primarily to optical navigation and photography assignments.

1.3 Attitude Data Generation

The attitude data required to analyze and define the various spacecraft attitude events were produced using the Apollo Mission Attitude Requirements (AMAR) Program. It should be noted that attitude maneuvers which reorient the spacecraft from an existing attitude are performed instantaneously in the AMAR simulation of the attitude event sequence. Maneuver times are shown for the applicable maneuvers in the cislunar portion of the timeline with the previous attitude carried through to the instantaneous initiation of the new orientation. The maneuver times are best estimates and are not intended to reflect actual reorientation procedures. Lunar orbit attitude maneuvers are computed using the maneuver rates and order of maneuvers presented in the Apollo 8 Final Flight Plan, Reference 2.

It should also be noted that the tabular attitude data will indicate, for certain cislunar event sequences, that no reorientation has occurred between events. For these situations, the spacecraft attitude constraints in the involved sequence are assumed to be satisfied by the initial orientation. Specific examples are discussed in the appropriate section.

1.4 Constraints

To facilitate discussion of the attitude event timeline, the primary spacecraft attitude constraints applicable to various phases or events in the mission are listed in this section.

1.4.1 Earth parking orbit constraints. -

1. The CSM attitude must provide continuous tracking, command, telemetry, and voice capabilities when line of sight to a MSFN station exists.

2. CSM gimbal lock must be avoided. For this mission, gimbal lock has been defined as an angle of 45 degrees or less between the outer gimbal axis and the inner gimbal axis.

1.4.2 Cislunar constraints. -

1. Continuous S-IVB tracking and telemetry are required for a 10-minute period within the first 20 minutes after TLI cutoff.

2. S-IVB tracking, telemetry and command and CSM tracking, telemetry and voice are required during the S-IVB/CSM separation maneuver.

3. Telemetry is required from the S-IVB for a minimum of 10 minutes following S-IVB/CSM separation.

4. CSM tracking, command, telemetry, and voice are required for one hour following S-IVB/CSM separation.

5. CSM gimbal lock must be avoided.

6. The S-IVB attitude at S-IVB/CSM separation must provide illumination of the forward end of the S-IVB to simulate the lighting for the LM extraction maneuver.

7. For midcourse correction (MCC) maneuvers, continuous CSM command, telemetry, and voice are required for the 1-hour period beginning 30 minutes before the MCC.

8. The maximum duration of a continuous inertial attitude hold for the CSM is determined by the RCS quads fracture mechanics constraint. The attitude hold limits due to this constraint are shown in Figure 1 in terms of solar aspect angles.

9. The ratio of thermal control time to attitude hold time should be at least 5 to 1.

10. For IMU alignments, the CSM inertial attitude must provide a suitable starfield for the optics field of view.

11. For IMU alignments, the sun line of sight must not be within 15 degrees of the sextant (SXT) boresight nor within 55 degrees of the scanning telescope (SCT).

12. For cislunar optical navigation, the sun line of sight must not be within 10 degrees of the landmark line of sight nor within 15 degrees of the star line of sight for the SXT.

13. For cislunar optical navigation, the separation of the two sextant (SXT) lines of sight is limited to 50 degrees.

14. For cislunar optical navigation, the sun elevation must be greater than 10 degrees for the star/earth horizon case and greater than 5 degrees for the star/lunar horizon case. The elevation angle is measured from the point of tangency of the respective horizon.

15. For passive thermal control (PTC), the earth line of sight should be 90 degrees (±45 degrees) from the spacecraft plus X-axis. This requirement is imposed for omni antenna-earth communications and also for earth or moon visibility. The initial PTC orientation will be determined by the reference body (earth or moon) involved in the following navigation sightings. Thus, the CSM X-axis would be aligned generally towards the earth (angle between earth line of sight and plus X-axis is from 45 to 90 degrees) for a following star/earth navigation sighting. For star/lunar sightings, the corresponding lunar line of sight-plus X-axis angle would be less than 90 degrees.

16. The sun must be within 20 degrees of the normal to the spacecraft X-axis during periods of PTC.

17. To minimize crew disorientation during PTC, the maximum out-of-plane (yaw) angle should be less than 20 degrees.

1.4.3 Lunar orbit constraints. - There are no unique CSM attitude constraints for the lunar orbit phase of the mission. Attitude requirements pertaining to cislunar optical navigation, IMU alignments, gimbal lock avoidance, and MSFN communications must be satisfied by appropriate attitude orientations in lunar orbit.

2. SYMBOLS

ALT	altitude
ARM06	Apollo Reference Mission Program Version ARM06
AMAR	Apollo Mission Attitude Requirements Program
AOS	acquisition of signal
CM	command module
CSM	command and service module
EMP	earth-moon plane
g.e.t.	ground elapsed time (hr:min:sec)
IGA	inner gimbal angle
IMU	inertial measurement unit
LAT	selenographic latitude
LM	lunar module
LMAB	Lunar Mission Analysis Branch
LOI-1	first lunar orbit insertion burn
LOI-2	lunar orbit circularization burn
LON	selenographic longitude
LOS	loss of signal
MCC	midcourse correction
MGA	middle gimbal angle
MPAD-MSC	Mission Planning and Analysis Division-Manned Spacecraft Center
MSFN	Manned Space Flight Network
OGA	outer gimbal angle
PTC	passive thermal control
RCS	reaction control system

REFSMMAT	reference to stable member coordinate transformation matrix
SCT	scanning telescope
SDA	shaft drive axis
SEH	star/earth horizon
SEL	star/earth landmark
SLA	spacecraft LM adapter
SLH	star/lunar horizon
SM	service module
SPS	service propulsion system
SXT	sextant
S-IVB	third stage of Saturn V vehicle
TE	transearth
TEI	transearth injection
TL	translunar
TLI	translunar injection
ΔV	velocity increment

3. EARTH ORBIT PHASE

The S-IVB/SLA/CSM configuration is inserted into a 100-nautical mile altitude circular parking orbit by the Saturn V booster at 00:11:20 g.e.t. The burnout attitude is held inertially fixed for 15 seconds after termination of the insertion burn. Following this hold, the S-IVB attitude control system positions the S-IVB (and CSM) X-axis along the local horizontal in the direction of motion. The CSM Z-axis is in the trajectory plane with the crew heads down. An S-IVB orbital pitch rate is then initiated in order to maintain this alignment locally fixed during the earth orbit phase of the mission. This attitude assures communication coverage during passes over MSFN stations. During the second revolution in earth parking orbit, the S-IVB will orient to the TLI burn attitude. The burn is performed under attitude control by the S-IVB guidance and control systems.

It should be noted at this point that the IMU gimbal angle data shown in the tables are based on the prelaunch REFSMMAT until the IMU is realigned prior to the last TL MCC. Gimbal angle measurements after this realignment will reflect the new IMU attitude reference as will be discussed in the appropriate section. Table III lists the direction cosines corresponding to the three IMU REFSMMAT alignments which are unique for the given launch date and launch azimuth.

Table II(a) lists the spacecraft position and attitude data for the earth orbit phase of the mission.

4. TRANSLUNAR PHASE

This section contains a brief description of major attitude events in the translunar phase of the mission. Most of these events, as noted in their descriptions, are also common to the transearth phase of the mission. Those events occurring only in the transearth phase will be described in Section 6. A graphical presentation of the major cislunar events is given in Figure 2. Spacecraft look angles and IMU gimbal angles for the translunar phase are given in Table II(b).

4.1 Post-TLI Sequence of Events

Following the termination of the TLI burn at 02:55:43 g.e.t., the burnout attitude is fixed inertially for 20 seconds. At the end of this time period, the local horizontal mode is again established by the S-IVB attitude control system for MSFN post-TLI checkout. Fifteen minutes after TLI cutoff, the S-IVB orients to the S-IVB/CSM separation attitude. Primary considerations involved in defining the separation attitude are communications, gimbal lock, and lighting on the forward end of the S-IVB. The lighting constraint is to evaluate illumination of the LM docking tunnel for later missions having the LM onboard. The orientation thus consists of a pitch maneuver to point the SLA generally towards the sun and a roll maneuver for communications. The separation attitude is held inertially fixed until a separation distance of about 50 feet is achieved between the S-IVB and CSM. The CSM is then pitched through 180 degrees to face the S-IVB. This attitude provides visual observation of the S-IVB and MSFN communications. The CSM flies formation for approximately 24 minutes and then orients to the evasive maneuver attitude. This attitude consists of the CSM X-axis being aligned along the negative position vector. The CSM minus Z-axis is oriented in the direction of motion and in the trajectory plane. The purpose of the orientation is to provide visual monitoring of the S-IVB and a nominal thrusting alignment for an RCS burn to avoid S-IVB recontact.

The evasive maneuver attitude is held inertially fixed until 04:00:00 g.e.t., at which time the CSM will be positioned to perform an IMU alignment.

The post-TLI sequence of events is illustrated in Figure 3. Numerical data for the post-TLI sequence were obtained from Reference 3.

4.2 Navigation Sightings

During the cislunar phase of the mission, optical navigation will be performed to determine onboard navigation capability. These sightings occur throughout the mission as noted in the tabular data. The various types of cislunar navigation sightings are

1. Star/earth horizon sightings - optical sightings taken on a reference star and the lighted earth horizon

2. Star/earth landmark sightings - optical sightings taken on a reference star and a known or unknown earth landmark

3. Star/lunar horizon sightings - optical sightings taken on a reference star and the lighted lunar horizon

The CSM orientation for optical sightings must consider requirements for communications and avoidance of gimbal lock as well as the optical pointing requirements. Sightings involving the earth horizon or landmarks can usually be accomplished at an attitude satisfying these requirements. This is caused by the fact that the CSM optics and S-band antenna are only 48 degrees apart and point in the same general direction. Lunar navigation sightings, however, produce attitudes inconsistent with S-band communications requirements for the same reason. Figure 4 illustrates the geometrical situation for both earth and lunar navigation sightings.

The AMAR simulation of cislunar navigation periods represents an approximation to the actual procedures and attitude maneuvers involved in performing the star/reference body sightings. This approximation consists of maintaining a local horizontal attitude hold (X-, Z-axes in the trajectory plane) with the shaft drive axis (SDA) aligned to the center of the reference body. A memorandum containing attitude data (gimbal angles) closely reflecting the onboard procedures will be published as soon as possible.

4.3 Passive Thermal Control

A nominal thermal environment is provided during the cislunar phase for temperature-critical spacecraft components by the passive thermal control (PTC) mode. The CSM PTC orientation consists of aligning the CSM X-axis within 20 degrees of the normal to the solar vector and rolling about the X-axis at one revolution per hour. Attitude control is maintained in wide angle deadband (± 5 degrees) in pitch and yaw when the PTC attitude is established. Roll axis control may then either be maintained or disabled. For simulation purposes in this timeline, the X-axis pointing was fixed.

The PTC orientations have also been optimized for earth or moon visibility and omni antenna coverage by positioning the X-axis as broadside to the reference body involved in the following navigation sightings as possible without violating the middle gimbal angle constraint. Figure 5 shows a typical PTC alignment.

It may be noted by referring to the tabular data that the lunar mission rule requiring a 5 to 1 ratio of PTC time to attitude-hold time is not satisfied for the major portion of this timeline. This is due primarily to the short translunar and transearth flight times. During the mission, the thermal control requirement could be met to some degree by a roll maneuver during spacecraft operations requiring only small attitude changes over a long period of time.

4.4 IMU Alignments

Following PTC periods and prior to the midcourse correction (MCC) maneuvers, onboard navigation, lunar orbit insertion, and entry, the crew will realign the IMU to preclude drift errors in targeting for these events.

The CSM cislunar IMU alignment attitude is involved primarily with obtaining a suitable starfield for the CSM optics. For generation of this attitude timeline, it has been assumed that the attitude preceding each IMU alignment, usually a PTC attitude, is acceptable for performing the alignment. This assumption implies that a suitable starfield should be available with the existing attitude. In the event of earth or lunar occlusion or the absence of a reference star at this attitude, a roll maneuver could be employed to obtain a reference star within a clear optics field of view. Although not simulated, the IMU alignment preceding a MCC maneuver is accomplished in the MCC burn attitude.

4.5 Midcourse Corrections

At specified times during the translunar and transearth phases of the mission, the ground will determine by state vector propagation if the current trajectory will satisfy desired end conditions. If the trajectory is deemed unacceptable, a midcourse correction maneuver will be performed by either the SPS or the RCS.

Since the MCC attitude is dependent on the type of adjustment maneuver required, this attitude cannot be described prior to the mission. Attitude data for the MCC events in this timeline were generated by assuming in-plane burn maneuvers with a burn ΔV of zero. The transearth MCC attitudes are with the thrust (X-)axis along the local horizontal with respect to the earth.

4.6 Pre-LOI Sequence of Events

The IMU alignment prior to the last translunar MCC will align the IMU to the LOI-2 REFSMMAT. The IMU alignment is to provide the crew with gimbal angles of 0, 180, 0 (roll, pitch, yaw) at the start of the LOI-2 burn.

After the time for the last translunar MCC, the CSM is aligned to the PTC orientation. Approximately 5 hours later, another IMU alignment is performed, after which the PTC mode is resumed. Approximately thirty minutes later, the CSM is oriented to the LOI-1 burn attitude, and a SXT star check and another IMU alignment is performed. This attitude is held inertially fixed through the LOI-1 burn.

5. LUNAR ORBIT PHASE

A detailed description of each revolution is included for the lunar orbit portion of the attitude sequence because of the many and varied events which occur. Lunar orbit attitude maneuvers are computed using the maneuver rates and maneuver order specified in the Apollo 8 Final Flight Plan, Reference 2. Instantaneous maneuvers are shown in the figures due to space limitations. Table II(c) presents the spacecraft positional and attitude data for the lunar orbit phase of the mission.

5.1 First Revolution (Figure 6)

The sequence of significant events that occur during the first revolution is as follows:

1. First lunar orbit insertion (LOI-1) burn
2. Acquisition of MSFN line of sight
3. Enter darkness
4. IMU realignment
5. Loss of MSFN line of sight
6. Enter sunlight
7. Lunar observation and photography

The LOI-1 burn deboosts the CSM from the cislunar trajectory into a 60-nautical mile by 170-nautical mile elliptical parking orbit. The burn is performed with the CSM in a retrograde attitude, and the crew is heads down to afford visual reference with the lunar surface. The LOI-1 burn attitude is held inertially fixed following the burn until immediately prior to acquisition of MSFN line of sight. The CSM is then rolled 180 degrees to establish S-band high-gain communications. The resulting attitude is held inertially fixed until approximately 10 minutes before loss of MSFN line of sight. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment which occurs immediately after the CSM enters darkness. The CSM is then maneuvered to an attitude which allows lunar visual observation and photography. The vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 45 degrees and a roll of 180 degrees. This attitude is held locally fixed through the completion of the first revolution.

5.2 Second Revolution (Figure 7)

The sequence of significant events that occur during the second revolution is as follows:

1. Lunar observation and photography

2. Acquisition of MSFN line of sight

3. TV transmission

4. Enter darkness

5. IMU realignment

6. Loss of MSFN line of sight

7. Enter sunlight

At the completion of the first revolution, the CSM is in a locally fixed attitude which allows lunar visual observation and photography. The local attitude hold is maintained until approximately 8 minutes prior to acquisition of MSFN line of sight. The CSM is then yawed 45 degrees to establish the TV sighting attitude. The vehicle attitude with respect to the local horizontal orientation is a pitch of minus 45 degrees, a yaw of minus 45 degrees, and a roll of 180 degrees. This attitude is maintained locally fixed for 20 minutes. The CSM is then maneuvered back to the locally fixed visual observation and photography attitude. This attitude is maintained until approximately 7 minutes before the CSM enters darkness.

At this time, the local attitude hold is terminated, and the existing vehicle attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment which occurs about 5 minutes after the CSM enters darkness. Approximately 8 minutes prior to the loss of MSFN line of sight, the inertial attitude hold is terminated, and the CSM is maneuvered to the circularization (LOI-2) burn attitude. This attitude is held inertially fixed through the remainder of the second revolution.

5.3 Third Revolution (Figure 8)

The sequence of significant events that occur during the third revolution is as follows:

1. Circularization burn

2. Acquisition of MSFN line of sight

3. Landmark training photography

4. Enter darkness

5. IMU realignment

6. Loss of MSFN line of sight

7. Enter sunlight

8. Orbital navigation photography

Immediately following the start of the third revolution, the circularization burn is performed. The circularization burn transforms the initial elliptical parking orbit into a 60-nautical mile circular orbit. The burn is performed with the CSM in a retrograde attitude, and the crew is heads down to afford visual reference with the lunar surface. Approximately 9 minutes after the burn, the CSM is maneuvered to an attitude which allows landmark familiarization and photography. In this exercise, the CSM X-axis cameras are given the same pointing profile that the CSM shaft drive axis (SDA) will have during landmark sightings. The vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 62 degrees and a roll of 180 degrees. This attitude is held locally fixed until the CSM cameras become pointed at the pseudo landing site landmark (Table IV). A manual pitch rate is then initiated to keep the cameras pointed at the landmark. Approximately 1.5 minutes after the CSM passes the closest point of approach to the landmark, the pitch rate is terminated, and the vehicle is maneuvered to the IMU realignment attitude. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 7 minutes after the CSM enters darkness. The inertial attitude hold is maintained until approximately 9 minutes before the CSM enters sunlight. The inertial attitude hold is then terminated, and the CSM is maneuvered to an attitude which allows orbital navigation photography. The vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 90 degrees and a roll of 180 degrees. This attitude is held locally fixed while the CSM X-axis cameras perform vertical stereo photography. The CSM windows are oriented away from the sun to allow better photography. This attitude is held locally fixed through the completion of the third revolution.

5.4 Fourth Revolution (Figure 9)

The sequence of significant events that occur during the fourth revolution is as follows:

1. Orbital navigation photography
2. Acquisition of MSFN line of sight
3. Landmark lighting evaluation
4. Enter darkness
5. IMU realignment
6. Loss of MSFN line of sight
7. Enter sunlight

At the start of the fourth revolution, the CSM is in the locally fixed orbital navigation photography attitude. The local attitude hold is maintained, and the vehicle is rolled minus 180 degrees as it passes over the sub-solar point to orient the windows away from the sun. Approximately

13 minutes before the CSM passes the closest point of approach to the pseudo landing site landmark, the CSM is maneuvered to the landmark lighting evaluation attitude. This attitude, with respect to the local horizontal orientation, is a pitch of minus 5 degrees. This attitude is maintained locally fixed until about 7 minutes after the CSM enters darkness. The CSM is then rolled 180 degrees to gain S-band high-gain communications, and the resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 9 minutes after the CSM enters darkness. About 9 minutes before the CSM enters sunlight, the inertial attitude hold is terminated, and the CSM is maneuvered to the initial landmark tracking attitude for the landmark sighting sequence which occurs early in the fifth revolution on the second control point landmark (Table IV). The initial landmark tracking attitude, which is a pitch of minus 5 degrees with respect to the local horizontal orientation, is held locally fixed through the completion of the fourth revolution.

5.5 Fifth Revolution (Figure 10)

The sequence of significant events that occur during the fifth revolution is as follows:

1. Landmark sighting on the second control point landmark
2. Acquisition of MSFN line of sight
3. Landmark sighting on the pseudo landing site landmark
4. Enter darkness
5. IMU realignment
6. Loss of MSFN line of sight
7. Enter sunlight

At the beginning of the fifth revolution, the CSM is in the initial tracking attitude for the landmark sighting sequence (Figure 11). The attitude at the beginning of a landmark sighting sequence, with respect to the local horizontal orientation, is a pitch of minus 5 degrees. This attitude is maintained locally fixed until the CSM is about 46 seconds from the closest point of approach to the landmark. The CSM is then given a minus 0.3 degree per second pitch rate to keep the landmark in the optics field of coverage throughout the tracking period. Approximately 91 seconds after the CSM passes the closest point of approach to the landmark, the pitch rate is terminated. This landmark tracking attitude sequence reflects current mission planning but should not be interpreted as the exact manner in which the sightings will be performed. The sighting sequence may be changed in real time dependent upon the crew's ability to recognize and track the landmarks. Also added in real time will be a slight roll maneuver to keep the optics trunnion angle greater than 10 degrees to avoid the optics blind zone region. It should

also be pointed out that the actual landmarks used for sightings may differ from those pre-selected for landmark sightings. This real time contingency could result from unexpected lighting conditions at the pre-selected landmarks or the achievement of an off-nominal lunar orbit which may place the pre-selected landmarks too far out of plane. Additionally, the crew's inability to recognize the pre-selected landmark could result in selecting and marking on a different landmark.

A landmark sighting sequence is performed on the second control point landmark, and the vehicle is maneuvered back to the initial landmark tracking attitude for a landmark sighting sequence on the pseudo landing site landmark. After the completion of the sighting sequence on the pseudo landing site landmark, the CSM is rolled 180 degrees to gain S-band high-gain communications, and the resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 10 minutes after the CSM enters darkness. About 8 minutes before the CSM enters sunlight, the inertial attitude hold is terminated, and the CSM is maneuvered to the initial landmark tracking attitude for a landmark sighting sequence, which occurs early in the sixth revolution on the second control point landmark. The landmark sighting attitude is held locally fixed through the completion of the fifth revolution.

5.6 Sixth Revolution (Figure 12)

The sequence of significant events that occur during the sixth revolution is as follows:

1. Landmark sighting on the second control point landmark
2. Acquisition of MSFN line of sight
3. Landmark sighting on the pseudo landing site landmark
4. Enter darkness
5. IMU realignment
6. Loss of MSFN line of sight
7. Enter sunlight
8. Landmark sighting on the first control point landmark

At the beginning of the sixth revolution, the CSM is in the locally fixed initial landmark tracking attitude. A landmark sighting sequence is performed on the second control point landmark, and then the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a landmark sighting sequence on the pseudo landing site landmark. After the completion of the sighting sequence on the pseudo landing site landmark, the CSM is rolled 180 degrees to gain S-band high-gain communications, and the resulting attitude is held inertially fixed. This inertially

fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 13 minutes after the CSM enters darkness. About 9 minutes before the CSM enters sunlight, the inertial attitude hold is terminated, and the CSM is maneuvered to the initial landmark tracking attitude for a landmark sighting sequence on the first control point landmark (Table IV). After the completion of the sighting sequence, the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a landmark sighting sequence, which occurs early in the seventh revolution on the second control point landmark. The initial landmark tracking attitude is held locally fixed through the completion of the sixth revolution.

5.7 Seventh Revolution (Figure 13)

The sequence of significant events that occur during the seventh revolution is as follows:

1. Landmark sighting on the second control point landmark
2. Acquisition of MSFN line of sight
3. Landmark sighting on the third control point landmark
4. Landmark sighting on the pseudo landing site landmark
5. Enter darkness
6. IMU realignment
7. Loss of MSFN line of sight
8. Enter sunlight
9. Landmark sighting on the first control point landmark

At the beginning of the seventh revolution, the CSM is in the locally fixed initial landmark tracking attitude. A landmark sighting sequence is performed on the second control point landmark, and then the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a landmark sighting sequence on the third control point landmark (Table IV). Upon completion of the sighting on the third control point landmark, the CSM is maneuvered back to the locally fixed initial landmark tracking attitude for a landmark sighting sequence on the pseudo landing site landmark. After the completion of the sighting sequence on the pseudo landing site landmark, the CSM is rolled 180 degrees to gain S-band high-gain communications, and the resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 8 minutes after the CSM enters darkness. About 9 minutes before the CSM enters sunlight, the inertial attitude hold is terminated, and the CSM is maneuvered to the initial landmark tracking attitude for a landmark sighting sequence on the first control point landmark. After the completion of the sighting

sequence, the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a landmark sighting sequence, which occurs early in the eight revolution on the second control point landmark. The initial landmark sighting attitude is held locally fixed through the completion of the seventh revolution.

5.8 Eight Revolution (Figure 14)

The sequence of significant events that occur during the eight revolution is as follows:

1. Landmark sighting on the second control point landmark
2. Acquisition of MSFN line of sight
3. Landmark sighting on the third control point landmark
4. Landmark sighting on the pseudo landing site landmark
5. Enter darkness
6. IMU realignment
7. Loss of MSFN line of sight
8. Dark side and solar corona photography
9. Enter sunlight
10. Orbital navigation photography (convergent stereo photography)

At the beginning of the eight revolution, the CSM is in the locally fixed initial landmark tracking attitude. A landmark sighting sequence is performed on the second control point landmark, and then the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a landmark sighting sequence on the third control point landmark. Upon completion of the sighting on the third control point landmark, the CSM is maneuvered back to the locally fixed initial landmark tracking attitude for a landmark sighting sequence on the pseudo landing site landmark. After the completion of the sighting sequence on the pseudo landing site landmark, the CSM is rolled 180 degrees to gain S-band high-gain communications, and the resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 9 minutes after the CSM enters darkness. Seventeen minutes before the CSM enters sunlight, the inertial attitude hold is terminated, and the CSM is maneuvered to an attitude which allows dark side and solar corona photography. The vehicle attitude, with respect to the local horizontal orientation, is a roll of 180 degrees. This attitude is held locally fixed until the CSM enters sunlight. The CSM is then maneuvered to an attitude which allows orbital navigation photography. This vehicle attitude, with respect to the local horizontal

orientation, is a pitch of minus 70 degrees and a roll of 180 degrees. The attitude is held locally fixed through the completion of the eighth revolution.

5.9 Ninth Revolution (Figure 15)

The sequence of significant events that occur during the ninth revolution is as follows:

1. Orbital navigation photography (convergent stereo photography)
2. Acquisition of MSFN line of sight
3. TV transmission
4. Enter darkness
5. IMU realignment
6. Loss of MSFN line of sight
7. Lunar observation
8. Enter sunlight

At the start of the ninth revolution, the CSM is in the orbital navigation photography attitude. This attitude is held locally fixed until the CSM passes over the subsolar point. The CSM is then pitched 40 degrees and rolled to shade the windows from the sun. The resulting attitude is held locally fixed while the convergent stereo photography continues and S-band high-gain communications are established for TV transmission. Approximately 1 minute after the CSM enters darkness, the local attitude hold is terminated, and the CSM is maneuvered to the IMU realignment attitude. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 15 minutes after the CSM enters darkness. At the loss of MSFN line of sight, the inertial attitude hold is terminated, and the CSM is maneuvered to a lunar observation attitude. The vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 90 degrees and a roll of 180 degrees. This attitude is held locally fixed until approximately 10 minutes after the CSM enters sunlight. The CSM is then maneuvered to the TEI burn attitude for a SXT star check. This attitude is held inertially fixed through the completion of the ninth revolution.

5.10 Tenth Revolution (Figure 16)

The sequence of significant events that occur during the tenth revolution is as follows:

1. Acquisition of MSFN line of sight

2. Enter darkness

3. IMU realignment

4. Loss of MSFN line of sight

5. Enter sunlight

6. Transearth injection (TEI) burn

At the start of the tenth revolution, the CSM is maneuvered back to the locally fixed lunar observation attitude. Approximately 20 minutes before the CSM enters darkness, the local attitude hold is terminated, and the existing attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment beginning as the CSM enters darkness. Approximately 7 minutes before loss of MSFN line of sight, the inertial attitude hold is terminated, and the vehicle is maneuvered to the TEI burn attitude. The burn attitude is then held inertially fixed prior to the burn. The TEI burn boosts the CSM from the 60-nautical mile circular lunar orbit into the transearth trajectory. The burn is performed with the CSM in a posigrade attitude, and the crew is heads down to afford visual reference with the lunar surface.

6. TRANSEARTH PHASE

Spacecraft look angles and IMU gimbal angles for the major events during the transearth phase of the mission are given in Table II(d).

6.1 Post-TEI Sequence of Events

Cutoff of the TEI burn occurs at 89:18:33 g. e. t. Following the burn termination, the CSM X-axis is positioned along the negative moon radius vector with the Z-axis in the direction of motion and in the plane of the trajectory. This orientation provides the crew with visual observation of the moon and is also acceptable for S-band/MSFN communications when earth line of sight is acquired.

Approximately one hour after TEI, the IMU will be aligned to the entry REFSMMAT. The IMU gimbal angles in the tabular attitude data thus will reflect the change in the alignment of the IMU. Following the IMU alignment, star/lunar horizon navigation sightings will be performed. The spacecraft will then be oriented for the first transearth PTC period.

6.2 Pre-Entry Sequence of Events

Following the time set for the last MCC (two hours prior to entry), the crew performs an IMU realignment. This alignment is performed in the entry attitude which is a pitch maneuver of 156 degrees from the entry REFSMMAT alignment of 0, 0, 0 (roll, pitch, yaw) gimbal angles. This maneuver results in a heads-down retrograde attitude held inertially fixed until approximately 17 minutes prior to entry. At this time, the spacecraft orients to the CM/SM separation attitude with the X-axis in a retrograde position 32 degrees below the local horizontal. The spacecraft is yawed positively through 45 degrees, and the crew is heads down. After separation, at entry minus 15 minutes, the CM returns to the entry attitude. The CM/SM separation and spacecraft entry attitude are shown in Figures 17a and 17b, respectively.

Table I. Mission Apollo 8 Event Sequence
(a) Translunar

Mission Time (hr:min:sec)	Event
2:50:31	TLI initiation
2:55:43	TLI cutoff
3:10:43	S-IVB/CSM separation attitude hold
3:20:43	S-IVB/CSM separation
3:21:43	Pitch 180 deg
3:45:00	Evasive maneuver
3:50:00	Orient to IMU realignment attitude
4:00:00	Perform IMU realignment
4:20:00	Complete IMU realignment and orient to SEH navigation sighting attitude
4:30:00	Perform SEH navigation sightings
5:20:00	Complete navigation sightings and orient to PTC attitude
5:30:00	Start PTC
8:00:00	Complete PTC and orient to IMU realignment attitude
8:10:00	Perform IMU realignment
8:30:00	Complete IMU realignment
9:00:00	Initiate spacecraft midcourse correction
9:10:00	Orient to SEL navigation sighting attitude
9:20:00	Perform SEL navigation sightings
9:50:00	Complete navigation sightings and orient to PTC attitude
10:00:00	Start PTC
16:20:00	Complete PTC and orient to IMU realignment attitude
16:30:00	Perform IMU realignment
16:50:00	Complete IMU realignment and orient to SEH navigation sighting attitude
17:00:00	Perform SEH navigation sightings
17:50:00	Complete navigation sightings and orient to PTC attitude
18:00:00	Start PTC

Table I. Mission Apollo 8 Event Sequence
(a) Translunar (Continued)

Mission Time (hr:min:sec)	Event
25:50:00	Complete PTC and orient to IMU realignment attitude
26:00:00	Perform IMU realignment
26:20:00	Complete IMU realighment and orient to SEH navigation sighting attitude
26:30:00	Perform SEH navigation sightings
27:00:00	Complete navigation sightings
27:30:00	Orient to MCC burn attitude
28:00:00	Initiate spacecraft midcourse correction
28:10:00	Orient to SEH navigation sighting attitude
28:20:00	Perform SEH navigation sightings
29:00:00	Complete navigation sightings and orient to PTC attitude
29:10:00	Start PTC
31:15:00	Perform TV sightings in PTC attitude
31:30:00	Complete TV sightings
33:40:00	Complete PTC and orient to IMU realignment attitude
33:50:00	Perform IMU realignment
34:10:00	Complete IMU realignment and orient to SEH navigation sighting attitude
34:20:00	Perform SEH navigation sightings
34:50:00	Complete navigation sightings and orient to PTC attitude
35:00:00	Start PTC
44:30:00	Complete PTC and orient to IMU realignment attitude
44:40:00	Perform IMU realignment
45:00:00	Complete IMU realignment and orient to SLH navigation sighting attitude
45:10:00	Perform SLH navigation sightings
46:00:00	Complete SLH navigation sightings
46:30:00	Orient to MCC burn attitude
47:00:00	Initiate spacecraft midcourse correction

Table I. Mission Apollo 8 Event Sequence
(a) Translunar (Continued)

Mission Time (hr:min:sec)	Event
47:10:00	Orient to SEH navigation sighting attitude
47:20:00	Perform SEH navigation sightings
47:50:00	Complete navigation sightings and orient to PTC attitude
48:00:00	Start PTC
51:40:00	Complete PTC and orient to IMU realignment attitude
51:50:00	Perform IMU realignment
52:10:00	Complete IMU realignment and orient to SLH navigation sighting attitude
52:20:00	Perform SLH navigation sightings
53:10:00	Complete navigation sightings and orient to PTC attitude
53:20:00	Start PTC
55:05:00	Complete PTC and orient to TV sighting attitude
55:15:00	Perform TV sightings
55:30:00	Complete TV sightings and orient to PTC attitude
55:40:00	Start PTC
60:00:00	Complete PTC and orient to IMU alignment attitude (Change to LOI-2 REFSMMAT)
60:10:00	Perform IMU alignment
60:30:00	Complete IMU alignment
61:00:00	Initiate spacecraft midcourse correction
61:10:00	Orient to PTC attitude
61:20:00	Start PTC
65:50:00	Complete PTC and orient to IMU realignment attitude
66:00:00	Perform IMU realignment
66:20:00	Complete IMU realignment and orient to PTC attitude
66:30:00	Start PTC
66:50:00	Complete PTC and orient to LOI-1 attitude

Table I. Mission Apollo 8 Event Sequence
(a) Translunar (Continued)

Mission Time (hr:min:sec)	
67:00:00	Perform sextant star check
67:10:00	Complete sextant star check and orient to PTC attitude
67:20:00	Start PTC
68:00:00	Complete PTC and orient to IMU realignment attitude
68:10:00	Perform IMU realignment
68:30:00	Complete IMU realignment
69:07:29	Initiate LOI-1 burn

Table I. Mission Apollo 8 Event Sequence
(b) Lunar Orbit

Mission Time (hr:min:sec)	Event
69:11:35	LOI-1 cutoff
69:28:50	Begin 180 deg roll for communications
69:30:20	Complete 180 deg roll, inertial attitude hold
69:30:20	Acquire Honeysuckle Creek line of sight
70:14:12	Enter lunar umbra, begin IMU realignment
70:36:35	Acquire Madrid line of sight
70:45:00	Begin maneuver to lunar observation and photography attitude
70:54:58	Lose Madrid line of sight
70:55:13	Lose Honeysuckle Creek line of sight
70:59:54	Complete maneuver to lunar observation and photography attitude, local attitude hold
71:00:26	Enter sunlight
71:30:00	Begin maneuver to TV attitude
71:35:00	Complete maneuver to TV attitude, local attitude hold
71:38:25	Acquire Madrid line of sight
71:38:35	Acquire Honeysuckle Creek line of sight
71:50:00	Begin maneuver to lunar observation attitude
71:55:00	Complete maneuver to lunar observation attitude, local attitude hold
72:08:30	Lose Honeysuckle Creek line of sight
72:15:00	Terminate local hold, begin inertial hold
72:22:47	Enter lunar umbra
72:27:00	Begin IMU realignment
72:55:00	Begin maneuver to circularization burn attitude
72:57:47	Complete maneuver to circularization burn attitude
73:03:18	Lose Madrid line of sight
73:09:01	Enter sunlight
73:30:54	Initiate circularization burn
73:31:04	Circularization burn cutoff, inertial attitude hold

Table I. Mission Apollo 8 Event Sequence
(b) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event
73:40:00	Begin maneuver to landmark training photography attitude
73:47:11	Complete maneuver to landmark training photography attitude, local attitude hold
73:47:48	Acquire Madrid line of sight
74:14:15	Start manual pitch rate for landmark training photography
74:16:33	Terminate pitch rate, begin maneuver to IMU realignment attitude
74:22:53	Enter lunar umbra
74:26:00	Complete maneuver to IMU realignment attitude, inertial attitude hold
74:30:00	Begin IMU realignment
74:59:49	Lose Madrid line of sight
75:00:00	Begin maneuver to orbital navigation photography attitude
75:09:00	Enter sunlight
75:15:23	Complete maneuver to orbital navigation photography attitude, local attitude hold
75:46:00	Begin 180 deg roll, maintain orbital rate
75:46:11	Acquire Madrid line of sight
75:47:30	Complete 180 deg roll, local attitude hold
76:00:00	Begin maneuver to landmark evaluation attitude
76:05:39	Complete maneuver to landmark evaluation attitude, local attitude hold
76:21:29	Enter lunar umbra
76:28:00	Terminate orbital rate, begin 180 deg roll
76:29:30	Complete 180 deg roll, inertial attitude hold
76:30:00	Begin IMU realignment
76:58:10	Lose Madrid line of sight
76:58:30	Begin maneuver to landmark sighting attitude
77:07:35	Enter sunlight
77:10:50	Complete maneuver to landmark sighting attitude, local attitude hold

Table I. Mission Apollo 8 Event Sequence
(b) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event
77:31:20	Begin -0.3 deg/sec pitch rate for second control point landmark sighting
77:33:37	Terminate pitch rate, begin maneuver to landmark sighting attitude
77:35:54	Complete maneuver to landmark sighting attitude, local attitude hold
77:44:32	Acquire Madrid line of sight
78:08:09	Acquire Goldstone line of sight
78:10:47	Begin -0.3 deg/sec pitch rate for pseudo landing site sighting
78:13:05	Terminate pitch rate, begin 180 deg roll
78:14:35	Complete 180 deg roll, inertial attitude hold
78:20:05	Enter lunar umbra
78:30:00	Begin IMU realignment
78:56:11	Lose Goldstone line of sight
78:56:32	Lose Madrid line of sight
78:58:30	Begin maneuver to landmark sighting attitude
79:06:12	Enter sunlight
79:12:04	Complete maneuver to landmark sighting attitude, local attitude hold
79:29:37	Begin -0.3 deg/sec pitch rate for second control point landmark sighting
79:31:51	Terminate pitch rate, begin maneuver to landmark sighting attitude
79:34:08	Complete maneuver to landmark sighting attitude, local attitude hold
79:42:30	Acquire Goldstone line of sight
79:42:51	Acquire Madrid line of sight
80:09:03	Begin -0.3 deg/sec pitch rate for pseudo landing site sighting
80:11:21	Terminate pitch rate, begin 180 deg roll
80:12:51	Complete 180 deg roll, inertial attitude hold
80:18:41	Enter lunar umbra

Table I. Mission Apollo 8 Event Sequence
(b) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event
80:32:00	Begin IMU realignment
80:54:28	Lose Goldstone line of sight
80:54:50	Lose Madrid line of sight
80:55:51	Begin maneuver to landmark sighting attitude
81:04:48	Enter sunlight
81:09:06	Complete maneuver to landmark sighting attitude, local attitude hold
81:14:00	Begin -0.3 deg/sec pitch rate for first control point landmark sighting
81:16:18	Terminate pitch rate, begin maneuver to landmark sighting attitude
81:18:35	Complete maneuver to landmark sighting attitude, local attitude hold
81:27:54	Begin -0.3 deg/sec pitch rate for second control point landmark sighting
81:30:11	Terminate pitch rate, begin maneuver to landmark sighting attitude
81:32:28	Complete maneuver to landmark sighting attitude, local attitude hold
81:40:51	Acquire Goldstone line of sight
81:46:59	Begin -0.3 deg/sec pitch rate for third control point landmark sighting
81:49:17	Terminate pitch rate, begin maneuver to landmark sighting attitude
81:51:34	Complete maneuver to landmark sighting attitude, local attitude hold
82:07:19	Begin -0.3 deg/sec pitch rate for pseudo landing site sighting
82:09:37	Terminate pitch rate, begin 180 deg roll
82:11:07	Complete 180 deg roll, inertial attitude hold
82:17:17	Enter lunar umbra
82:25:00	Begin IMU realignment
82:52:49	Lose Goldstone line of sight
82:54:07	Begin maneuver to landmark sighting attitude

Table I. Mission Apollo 8 Event Sequence
(b) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event
83:03:24	Enter sunlight
83:07:22	Complete maneuver to landmark sighting attitude, local attitude hold
83:12:17	Begin -0.3 deg/sec pitch rate for first control point landmark sighting
83:14:34	Terminate pitch rate, begin maneuver to landmark sighting attitude
83:16:51	Complete maneuver to landmark sighting attitude, local attitude hold
83:26:10	Begin -0.3 deg/sec pitch rate for second control point landmark sighting
83:28:28	Terminate pitch rate, begin maneuver to landmark sighting attitude
83:30:45	Complete maneuver to landmark sighting attitude, local attitude hold
83:39:13	Acquire Goldstone line of sight
83:45:16	Begin -0.3 deg/sec pitch rate for third control point landmark sighting
83:45:31	Acquire Honeysuckle Creek line of sight
83:47:34	Terminate pitch rate, begin maneuver to landmark sighting attitude
83:49:51	Complete maneuver to landmark sighting attitude, local attitude hold
84:05:35	Begin -0.3 deg/sec pitch rate for pseudo landing site sighting
84:07:53	Terminate pitch rate, begin 180 deg roll
84:09:23	Complete 180 deg roll, inertial attitude hold
84:15:54	Enter lunar umbra
84:25:00	Begin IMU realignment
84:45:00	Begin maneuver to darkside and solar corona photography attitude
84:50:47	Lose Honeysuckle Creek line of sight
84:51:14	Lose Goldstone line of sight
84:53:12	Complete maneuver to darkside and solar corona photography attitude, local attitude hold

Table I. Mission Apollo 8 Event Sequence
(b) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event
85:02:00	Enter sunlight, begin maneuver to orbital navigation photography attitude
85:04:36	Complete maneuver to orbital navigation photography attitude, local attitude hold
85:37:00	Begin pitch of 40 deg and roll to shade windows
85:37:06	Acquire Honeysuckle Creek line of sight
85:37:35	Acquire Goldstone line of sight
85:42:28	Complete maneuver for orbital navigation photography, local attitude hold
86:14:30	Enter lunar umbra
86:16:00	Begin maneuver to IMU realignment attitude
86:20:35	Complete maneuver to IMU realignment attitude, inertial attitude hold
86:30:00	Begin IMU realignment
86:49:05	Lose Honeysuckle Creek line of sight
86:49:35	Lose Goldstone line of sight
86:50:00	Begin maneuver to lunar observation attitude
87:00:37	Enter sunlight
87:04:25	Complete maneuver to lunar observation attitude, local attitude hold
87:10:00	Begin maneuver to TEI burn attitude
87:15:06	Complete maneuver to TEI burn attitude, inertial attitude hold
87:20:06	Begin maneuver to lunar observation attitude
87:30:21	Complete maneuver to lunar observation attitude, local attitude hold
87:35:27	Acquire Honeysuckle Creek line of sight
87:35:54	Acquire Goldstone line of sight
87:53:00	Terminate local attitude hold, inertial attitude hold
88:13:05	Enter lunar umbra, begin IMU realignment
88:40:00	Begin maneuver to TEI burn attitude
88:47:25	Lose Honeysuckle Creek line of sight

Table I. Mission Apollo 8 Event Sequence
(b) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event
88:47:53	Lose Goldstone line of sight
88:54:02	Complete maneuver to TEI burn attitude, inertial attitude hold
88:59:12	Enter sunlight
89:15:07	Initiate TEI burn

Table I. Mission Apollo 8 Event Sequence
(c) Transearth

Mission Time (hr:min:sec)	Event
89:18:33	TEI cutoff, orient +X down along local vertical, +Z forward, inertial hold
90:00:00	Orient to IMU alignment attitude
90:10:00	Perform IMU alignment (change to entry REFSMMAT)
90:30:00	Complete IMU alignment and orient to SLH navigation sighting attitude
90:40:00	Perform SLH navigation sightings
92:00:00	Complete navigation sightings and orient to PTC attitude
92:10:00	Start PTC
95:55:00	End PTC and orient to IMU realignment attitude
96:05:00	Perform IMU realignment
96:25:00	Complete IMU realignment and orient to PTC attitude
96:35:00	Start PTC
99:50:00	End PTC and orient to IMU realignment attitude
100:00:00	Perform IMU realignment
100:20:00	Complete IMU realignment and orient to SLH navigation sighting attitude
100:30:00	Perform SLH navigation sightings
101:00:00	Complete navigation sightings
101:20:00	Orient to SEH navigation sighting attitude
101:30:00	Perform SEH navigation sightings
102:30:00	Complete navigation sightings and orient to IMU realignment attitude
102:40:00	Perform IMU realignment
103:00:00	Complete IMU realignment

Table I. Mission Apollo 8 Event Sequence
(c) Transearth (Continued)

Mission Time (hr:min:sec)	Event
103:30:00	Roll 180 degrees for thermal control
104:00:00	Initiate spacecraft midcourse correction
104:30:00	Roll 180 degrees for thermal control
105:00:00	Orient to SEH navigation sighting attitude
105:10:00	Perform SEH navigation sightings
106:00:00	Complete navigation sightings and orient to SLH navigation sighting attitude
106:10:00	Perform SLH navigation sightings
106:40:00	Complete navigation sightings
107:20:00	Orient to IMU realignment attitude
107:30:00	Perform IMU realignment
107:50:00	Complete IMU realignment and orient to SEH navigation sighting attitude
108:00:00	Perform SEH navigation sightings
108:50:00	Complete navigation sightings and orient to PTC attitude
109:00:00	Start PTC
114:50:00	End PTC and orient to IMU realignment attitude
115:00:00	Perform IMU realignment
115:20:00	Complete IMU realignment and orient to PTC attitude
115:30:00	Start PTC
120:00:00	End PTC and orient to SEH navigation sighting attitude
120:10:00	Perform SEH navigation sightings
120:30:00	Complete navigation sightings
121:00:00	Orient to IMU realignment attitude
121:10:00	Perform IMU realignment
121:30:00	Complete IMU realignment

Table I. Mission Apollo 8 Event Sequence
(c) Transearth (Continued)

Mission Time (hr:min:sec)	Event
122:00:00	Initiate spacecraft midcourse correction
122:20:00	Orient to SLH navigation sighting attitude
122:30:00	Perform SLH navigation sightings
123:00:00	Complete navigation sightings
123:20:00	Orient to SEH navigation sighting attitude
123:30:00	Perform SEH navigation sightings
124:20:00	Complete navigation sightings and orient to PTC attitude
124:30:00	Start PTC
129:20:00	End PTC and orient to IMU realignment attitude
129:30:00	Perform IMU realignment
129:50:00	Complete IMU realignment and orient to SLH navigation sighting attitude
130:00:00	Perform SLH navigation sightings
130:30:00	Complete navigation sightings and orient to SEH navigation sighting attitude
130:40:00	Perform SEH navigation sightings
131:50:00	Complete navigation sightings and orient to PTC attitude
132:00:00	Start PTC
135:15:00	End PTC and orient to IMU realignment attitude
135:25:00	Perform IMU realignment
135:45:00	Complete IMU realignment and orient to PTC attitude
135:55:00	Start PTC
139:10:00	End PTC and orient to IMU realignment attitude
139:20:00	Perform IMU realignment
139:40:00	Complete IMU realignment and orient to PTC attitude
139:50:00	Start PTC
143:40:00	End PTC and orient to IMU realignment attitude

Table I. Mission Apollo 8 Event Sequence
(c) Transearth (Continued)

Mission Time (hr:min:sec)	Event
143:50:00	Perform IMU realignment
144:10:00	Complete IMU realignment
144:50:00	Initiate spacecraft midcourse correction
145:30:00	Orient to IMU realignment attitude (entry attitude)
145:40:00	Perform IMU realignment
146:00:00	Complete IMU realignment
146:32:30	Orient to CM/SM separation attitude
146:34:30	CM/SM separation
146:49:30	Entry

Table II. Mission Apollo 8 Spacecraft Attitude Data
(a) Earth Orbit

Mission Time (hr:min:sec)	Event	Geographic Position			Local Horizontal Attitude			IMU Gimbal Angles			Comments
		Attitude* (n mi)	Latitude* (deg)	Longitude* (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	
00:11:20	Earth orbit insertion	103.3	32.5	-54.3	0.0	0.0	180.0	-115.3	0.6	-179.2	Inertial hold
00:11:35	Begin local attitude hold	103.3	32.5	-52.8	0.0	0.0	180.0	-115.3	0.6	-179.2	
02:50:31	Initiate TLI burn	99.5	9.5	-165.9	0.0	0.0	180.0	-45.8	1.1	179.3	Terminate local attitude hold

*Altitude is measured with respect to the Fischer reference ellipsoid; latitude and longitude are measured positive north of the equator and east from the Greenwich meridian, respectively.

Table II. Mission Apollo 8 Spacecraft Attitude Data
(b) Translunar

Mission Time (hr:min:sec)	Event	IMU Gimbal Angle IGA (deg)	IMU Gimbal Angle MGA (deg)	IMU Gimbal Angle OGA (deg)	Look Angle to Earth Theta (deg)	Look Angle to Earth Phi (deg)	Look Angle to Moon Theta (deg)	Look Angle to Moon Phi (deg)	Look Angle to Sun Theta (deg)	Look Angle to Sun Phi (deg)	Comments
2:55:43	TLI cutoff	19.5	3.9	-179.8	90.0	0.0	50.3	-44.0	45.7	-81.8	Inertial hold at cutoff not simulated
2:56:03	Begin local altitude hold	19.5	3.9	-179.8	90.0	0.0	50.3	-44.0	45.7	-81.8	Local hold
3:10:43	S-IVB/CSM hold separation attitude	71.2	2.6	-2.9	160.0	0.0	93.0	147.1	69.3	130.8	Begin inertial hold
3:20:43	S-IVB/CSM separation	71.2	2.6	-2.9	140.5	0.0	93.3	146.7	69.3	130.8	
3:21:43	Pitch 180 deg	-108.8	-2.6	2.9	39.5	180.0	86.7	33.3	110.6	49.2	5.0 deg/sec maneuver rate
3:45:00	Evasive maneuver	-168.3	-3.8	-0.7	0.0	-3.2	132.9	49.5	134.9	89.3	Acquire S-IVB in window
3:50:00	Orient for IMU realignment	-170.9	-3.8	-0.9	0.0	-4.0	134.5	51.6	134.9	91.9	0.5 deg/sec maneuver rate*
4:00:00	Perform IMU realignment	-175.3	-3.7	-1.2	0.0	-2.8	136.9	55.3	134.6	96.2	
4:20:00	Complete IMU realignment; orient for navigation sightings	178.4	-3.6	-1.6	0.0	-2.3	139.8	61.8	133.6	102.3	0.5 deg/sec maneuver rate
4:30:00	Perform SEH navigation sightings	-126.4	-3.3	2.0	57.5	180.0	100.7	35.5	121.4	56.0	Begin local hold
5:20:00	Complete navigation sightings; orient for PTC	-134.6	-3.6	1.5	57.5	180.0	107.2	37.6	125.7	60.6	0.5 deg/sec maneuver rate
5:30:00	Start PTC	-118.1	20.0	2.7	76.3	-174.1	79.7	34.5	97.2	55.9	Roll at 0.1 deg/sec
8:00:00	Complete PTC; orient for IMU realignment	-118.1	20.0	-117.3	86.7	-58.6	79.3	156.6	97.1	175.8	0.5 deg/sec maneuver rate
8:10:00	Perform IMU realignment	-23.9	2.7	-147.7	180.0	-179.6	37.8	-120.8	54.5	-149.1	Begin inertial hold
8:30:00	Complete IMU realign; orient for MCC	-23.9	2.7	-147.7	179.2	150.5	38.0	-120.9	54.5	-149.1	Random burn attitude*
9:00:00	Initiate midcourse correction	-23.9	2.7	-147.7	178.1	150.5	38.3	-121.1	54.4	-149.1	Continue inertial hold
9:10:00	Orient for navigation sightings	-23.9	2.7	-147.7	177.8	150.5	38.4	-121.1	54.4	-149.1	0.5 deg/sec maneuver rate
9:20:00	Perform SEL navigation sightings	-148.5	-3.8	0.6	57.5	180.0	117.4	44.4	131.4	70.5	Begin local hold
9:50:00	Complete navigation sightings; orient for PTC	-149.7	-3.8	0.6	57.5	180.0	118.2	45.3	131.8	71.5	0.5 deg/sec maneuver rate
10:00:00	Start PTC	-136.1	20.0	1.6	73.6	-172.6	91.6	44.2	104.8	66.0	Roll at 0.1 deg/sec
16:20:00	Complete PTC; orient for IMU realignment	-136.1	20.0	121.6	79.7	64.6	91.1	-72.9	104.8	-54.3	0.5 deg/sec maneuver rate*
16:30:00	Perform IMU realignment	-136.1	20.0	121.6	79.8	64.5	91.1	-72.8	104.8	-54.3	Begin inertial hold
16:50:00	Complete IMU realignment; orient for navigation sightings	-136.1	20.0	121.6	80.0	64.4	91.1	-72.7	104.8	-54.3	0.5 deg/sec maneuver rate
17:00:00	Perform SEH navigation sightings	-157.2	-3.8	0.1	57.5	180.0	122.6	52.4	133.7	77.7	Begin local hold
17:50:00	Complete navigation sightings; orient for PTC	-157.7	-3.8	0.1	57.5	180.0	122.9	53.0	133.8	78.1	0.5 deg/sec maneuver rate
18:00:00	Start PTC	-136.1	20.0	1.6	80.7	-175.9	91.1	47.8	104.8	65.6	Roll at 0.1 deg/sec
25:50:00	Complete PTC; orient for IMU realignment	-136.1	20.0	-58.4	84.0	-117.3	90.9	110.1	104.7	125.3	0.5 deg/sec maneuver rate*

*Maneuver not simulated

Table II. Mission Apollo 8 Spacecraft Attitude Data
(b) Translunar (Continued)

Mission Time (hr:min:sec)	Event	IMU Gimbal Angle IGA (deg)	IMU Gimbal Angle MGA (deg)	IMU Gimbal Angle OGA (deg)	Look Angle to Earth Theta (deg)	Look Angle to Earth Phi (deg)	Look Angle to Moon Theta (deg)	Look Angle to Moon Phi (deg)	Look Angle to Sun Theta (deg)	Look Angle to Sun Phi (deg)	Comments
26:00:00	Perform IMU realignment	-136.1	20.0	-58.4	84.0	-117.3	90.9	110.2	104.7	125.3	Begin inertial hold
26:20:00	Complete IMU realignment; orient for navigation sightings	-136.1	20.0	-58.4	84.1	-117.4	90.8	110.3	104.7	125.3	0.5 deg/sec maneuver rate
26:30:00	Perform SEH navigation sightings	-161.6	-3.5	0.0	57.5	180.0	124.5	58.2	134.3	81.3	Begin local hold
27:00:00	Complete navigation sightings	-161.8	-3.5	0.0	57.5	180.0	124.5	58.4	134.3	81.4	Continue local hold
27:30:00	Orient for midcourse correction	-161.8	-3.5	0.0	57.5	180.0	124.5	58.4	134.3	81.4	Random burn attitude
28:00:00	Initiate midcourse correction	-39.5	1.9	-132.8	179.8	135.8	48.4	-153.7	62.3	-171.2	
28:10:00	Orient for navigation sightings	-39.5	1.9	-132.8	179.8	135.8	48.4	-153.7	62.3	-171.2	0.5 deg/sec maneuver rate
28:20:00	Perform SEH navigation sightings	-162.2	-3.4	0.0	57.5	180.0	124.6	59.1	134.4	81.7	Begin local hold
29:00:00	Complete navigation sightings; orient for PTC	-162.4	-3.4	0.0	57.5	180.0	124.7	59.4	134.4	81.9	0.5 deg/sec maneuver rate
29:10:00	Start PTC	-136.1	20.0	1.6	85.0	-177.8	90.8	51.0	104.7	65.2	Roll at 0.1 deg/sec
31:15:00	Perform TV sightings in PTC attitude	-136.1	20.0	31.6	85.5	152.0	90.8	21.4	104.7	35.1	Continue 0.1 deg/sec roll rate
31:30:00	Complete TV sightings	-136.1	20.0	121.6	85.6	62.0	90.8	-68.5	104.7	-54.9	Continue 0.1 deg/sec roll rate
33:40:00	Complete PTC orient for IMU realignment	-136.1	20.0	-178.4	86.1	1.7	90.8	-128.1	104.7	-115.0	0.5 deg/sec maneuver rate*
33:50:00	Perform IMU realignment	-136.1	20.0	-178.4	86.2	1.7	90.8	-128.0	104.7	-115.0	Begin inertial hold
34:10:00	Complete IMU realignment; orient for navigation sightings	-136.1	20.0	-178.4	86.2	1.7	90.8	-128.0	104.7	-115.0	0.5 deg/sec maneuver rate
34:20:00	Perform SEH navigation sightings	-163.9	-3.0	0.2	57.5	180.0	124.8	61.5	134.3	82.8	Begin local hold
34:50:00	Complete navigation sightings; orient for PTC	-164.0	-3.0	0.2	57.5	180.0	124.8	61.7	134.2	82.9	0.5 deg/sec maneuver rate
35:00:00	Start PTC	-136.1	20.0	1.6	86.4	-178.4	90.8	52.2	104.7	64.9	Roll at 0.1 deg/sec
44:30:00	Complete PTC; orient for IMU realignment	-136.1	20.0	-178.4	88.2	0.9	90.8	-126.1	104.7	-115.5	0.5 deg/sec maneuver rate*
44:40:00	Perform IMU realignment	-136.1	20.0	-178.4	88.2	0.9	90.9	-126.1	104.7	-115.5	Begin inertial hold
45:00:00	Complete IMU realignment; orient for navigation sightings	-136.1	20.0	-178.4	88.3	0.9	90.9	-126.0	104.7	-115.5	0.5 deg/sec maneuver rate
45:10:00	Perform SLH navigation sightings	23.8	4.9	-59.5	112.6	59.7	57.5	180.0	45.2	164.4	Begin local hold
46:00:00	Complete navigation sightings	23.7	4.7	-59.6	112.6	59.7	57.6	179.8	45.4	164.3	Continue local hold
46:30:00	Orient for midcourse correction	23.7	4.7	-59.6	112.6	59.7	57.6	179.8	45.4	164.3	Random burn attitude
47:00:00	Initiate midcourse correction	-43.8	1.7	-126.0	179.9	126.3	53.5	-164.1	64.1	-179.7	
47:10:00	Orient for navigation sightings	-43.8	1.7	-126.0	179.9	126.2	53.6	-164.1	64.1	-179.7	0.5 deg/sec maneuver rate
47:20:00	Perform SEH navigation sightings	-166.5	-1.0	1.4	57.5	180.0	123.6	65.1	132.7	83.4	Begin local hold

*Maneuver not simulated

Table II. Mission Apollo 8 Spacecraft Attitude Data
(b) Translunar (Continued)

Mission Time (hr:min:sec)	Event	IMU Gimbal Angle IGA (deg)	IMU Gimbal Angle MGA (deg)	IMU Gimbal Angle OGA (deg)	Look Angle to Earth Theta (deg)	Look Angle to Earth Phi (deg)	Look Angle to Moon Theta (deg)	Look Angle to Moon Phi (deg)	Look Angle to Sun Theta (deg)	Look Angle to Sun Phi (deg)	Comments
47:50:00	Complete navigation sightings; orient for PTC	-166.5	-0.8	1.5	57.5	180.0	123.5	65.2	132.5	83.4	0.5 deg/sec maneuver rate
48:00:00	Start PTC	-136.1	20.0	1.6	88.7	-179.3	90.9	54.5	104.7	64.4	Roll at 0.1 deg/sec
51:40:00	Complete PTC; orient for IMU realignment	-136.1	20.0	-118.4	89.2	-59.5	91.0	175.2	104.6	-175.8	0.5 deg/sec maneuver rate*
51:50:00	Perform IMU realignment	-136.1	20.0	-118.4	89.3	-59.5	91.0	175.2	104.6	-175.8	Begin inertial hold
52:10:00	Complete IMU realignment; orient for navigation sightings	-136.1	20.0	-118.4	89.3	-59.5	91.0	175.3	104.6	-175.8	0.5 deg/sec maneuver rate
52:20:00	Perform SLH navigation sightings	25.2	5.7	-60.2	110.1	60.4	57.5	180.0	44.9	166.9	Begin local hold
53:10:00	Complete navigation sightings; orient for PTC	25.1	5.2	-60.4	110.1	60.4	57.9	179.8	45.3	166.9	0.5 deg/sec maneuver rate
53:20:00	Start PTC	-136.1	20.0	1.6	89.5	-179.5	91.0	55.6	104.6	64.1	Roll at 0.1 deg/sec
55:05:00	Complete PTC; orient for TV sighting	-136.1	20.0	1.6	89.7	-89.6	91.1	146.0	104.6	154.1	0.5 deg/sec maneuver rate
55:15:00	Perform TV sighting	-73.0	15.6	22.3	149.2	133.8	57.5	-30.0	72.1	23.7	Begin inertial hold
55:30:00	Complete TV sighting; orient for PTC	-73.0	15.6	22.3	149.2	133.7	57.6	-30.1	72.1	23.7	0.5 deg/sec maneuver rate
55:40:00	Start PTC	-136.1	20.0	1.6	89.7	-179.6	91.1	56.2	104.6	64.0	Roll at 0.1 deg/sec
60:00:00	Complete PTC; orient for IMU alignment	-136.1	20.0	121.6	90.3	60.3	91.3	-62.2	104.6	-56.1	0.5 deg/sec maneuver rate
60:10:00	Perform IMU alignment	0.0	0.0	0.0	72.8	-173.2	50.2	-2.5	43.0	14.9	Begin inertial hold; change to LOI-2REFSMMAT
60:30:00	Complete IMU align; orient for MCC	0.0	0.0	0.0	72.8	-173.2	50.1	-2.5	43.0	14.9	Random burn attitude*
61:00:00	Initiate midcourse correction	0.0	0.0	0.0	72.8	-173.3	49.8	-2.6	43.0	14.9	Continue inertial hold
61:10:00	Orient for PTC	0.0	0.0	0.0	72.8	-173.3	49.7	-2.6	43.0	14.9	0.5 deg/sec maneuver rate
61:20:00	Start PTC	-23.1	-20.0	-88.5	50.0	-100.2	73.0	92.7	70.8	107.4	Roll at 0.1 deg/sec
65:50:00	Complete PTC; orient for IMU realignment	-23.1	-20.0	91.5	50.1	79.2	67.2	-85.2	71.0	-72.6	0.5 deg/sec manuever rate*
66:00:00	Perform IMU realignment	-23.1	-20.0	91.5	50.1	79.2	66.7	-85.0	71.0	-72.6	Begin inertial hold
66:20:00	Complete IMU realignment; orient for PTC	-23.1	-20.0	91.5	50.2	79.2	65.6	-84.5	71.0	-72.6	0.5 deg/sec maneuver rate
66:30:00	Start PTC	-23.1	-20.0	-88.5	50.2	-100.8	64.9	95.7	71.0	107.4	Roll at 0.1 deg/sec
66:50:00	Complete PTC; orient to LOI -1 attitude	-23.1	-20.0	31.5	50.2	139.1	63.4	-23.7	71.0	-12.6	0.5 deg/sec maneuver rate
67:00:00	Perform sextant star check	-165.0	6.9	0.5	93.0	-6.0	156.1	169.2	147.9	147.7	Begin inertial hold
67:10:00	Complete sextant star check; orient for PTC	-165.0	6.9	0.5	93.0	-6.0	157.2	168.7	147.9	147.7	0.5 deg/sec maneuver rate
67:20:00	Start PTC	-23.1	-20.0	-88.5	50.3	-100.9	60.3	97.6	71.0	107.3	Roll at 0.1 deg/sec

*Maneuver not simulated

Table II. Mission Apollo 8 Spacecraft Attitude Data
(b) Translunar (Continued)

Mission Time (hr:min:sec)	Event	IMU Gimbal Angle IGA (deg)	IMU Gimbal Angle MGA (deg)	IMU Gimbal Angle OGA (deg)	Look Angle to Earth Theta (deg)	Look Angle to Earth Phi (deg)	Look Angle to Moon Theta (deg)	Look Angle to Moon Phi (deg)	Look Angle to Sun Theta (deg)	Look Angle to Sun Phi (deg)	Comments
68:00:00	Complete PTC; orient for IMU realignment	-23.1	-20.0	151.5	50.4	19.0	52.9	-138.8	71.1	-132.7	0.5 deg/sec maneuver rate
68:10:00	Perform IMU realignment	-165.0	6.9	0.5	92.8	-5.9	169.2	155.2	147.8	147.7	Begin inertial hold in LOI-1 burn attitude
68:30:00	Complete IMU realignment	-165.0	6.9	0.5	92.7	-5.9	175.	80.6	147.8	147.7	Continue inertial hold
69:07:29	Initiate LOI-1 burn	-165.0	6.9	0.5	No line of sight		97.9	0.0	147.8	147.8	

Table II. Mission Apollo 8 Spacecraft Attitude Data
(c) Lunar Orbit

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal Attitude			IMU Gimbal Angles			Look Angles To Earth		Look Angles To Sun		Look Angles To Landmark		Comments
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	
69:11:35	LOI Cutoff	59.4	-10.1	178.4	-171.6	6.9	0.5	-165.0	6.9	0.5	No line of sight		147.8	147.7			
69:28:50	Begin 180 deg roll for communications	74.7	-11.7	124.1	-118.5	6.9	0.5	-165.0	6.9	0.5	No line of sight		147.8	147.8			2.0 deg/sec roll rate
69:30:20	Complete 180 deg roll; acquire MSFN line of sight	77.7	-11.4	119.5	-114.0	6.9	-179.5	-165.0	6.9	-179.5	92.3	174.2	147.8	-32.3			Begin inertial hold
70:14:12	Enter lunar umbra; begin IMU realignment	167.4	9.7	0.9	5.3	6.9	-179.5	-165.0	6.9	-179.5	92.3	174.2	No line of sight				Continue inertial hold
70:45:00	Begin maneuver to lunar observation and photography attitude	129.8	9.2	-80.2	84.9	6.9	-179.5	-165.0	6.9	-179.5	93.5	174.3	No line of sight				0.2 deg/sec pitch-yaw rate
70:55:13	Lose MSFN line of sight	103.0	4.2	-108.8	-26.5	0.0	180.0	79.0	0.0	180.0	No line of sight		No line of sight				Continue maneuver
70:59:54	Complete maneuver to lunar observation and photography attitude	90.9	1.4	-121.8	-45.0	0.0	180.0	23.2	0.0	180.0	No line of sight		No line of sight				Begin local hold
71:00:26	Enter sunlight	89.6	1.1	-123.3	-45.0	0.0	180.0	21.7	0.0	180.0	No line of sight		23.1	-153.2			Continue local hold
71:30:00	Begin maneuver to TV attitude	63.3	-12.3	146.3	-45.0	0.0	180.0	-68.8	0.0	180.0	No line of sight		110.9	-169.1			0.2 deg/sec pitch-yaw rate
71:35:00	Complete maneuver to TV attitude	70.2	-12.1	130.5	-45.0	-45.0	180.0	-84.1	-45.0	180.0	No line of sight		122.5	160.1			Begin local hold
71:38:25	Acquire MSFN line of sight	76.6	-11.5	120.0	-45.0	-45.0	180.0	-94.4	-45.0	180.0	44.0	-122.9	129.3	150.3			Continue local hold
71:50:00	Begin maneuver to lunar observation attitude	104.5	-7.1	85.8	-45.0	-45.0	180.0	-128.3	-45.0	180.0	62.7	-158.7	144.3	105.6			-0.2 deg/sec pitch-yaw rate
71:55:00	Complete maneuver to lunar observation attitude	117.8	-4.4	71.9	-45.0	0.0	180.0	-142.3	0.0	180.0	70.5	174.1	168.7	-64.7			Begin local hold
72:15:00	Terminate local hold; begin inertial hold	160.4	6.5	19.7	-45.0	0.0	180.0	164.6	0.0	180.0	123.7	173.3	121.5	-11.9			Begin inertial hold
72:22:47	Enter lunar umbra	167.2	9.6	0.1	-25.5	0.0	180.0	164.6	0.0	180.0	123.9	173.3	No line of sight				Continue inertial hold
72:27:00	Begin IMU realignment	168.2	10.9	-11.0	-14.5	0.0	180.0	164.6	0.0	180.0	124.0	173.3	No line of sight				Continue inertial hold
72:55:00	Begin maneuver to circularization burn attitude	126.4	8.7	-85.1	58.2	0.0	180.0	164.6	0.0	180.0	124.4	173.3	No line of sight				2 deg/sec roll rate; 0.2 deg/sec pitch rate
72:57:47	Complete maneuver to circularization burn attitude	122.4	7.9	-93.2	82.0	0.0	0.0	180.0	0.0	0.0	109.1	-5.8	No line of sight				Begin inertial hold
73:03:18	Lose MSFN line of sight	104.5	4.5	-108.2	96.8	0.0	0.0	180.0	0.0	0.0	No line of sight		No line of sight				Continue inertial hold
73:09:01	Enter sunlight	89.9	1.1	-124.3	113.1	0.0	0.0	180.0	0.0	0.0	No line of sight		136.5	165.2			Continue inertial hold
73:30:54	Circularization burn initiation	59.0	-10.8	169.6	179.7	0.0	0.0	180.0	0.0	0.0	No line of sight		136.4	165.2			SPS burn
73:31:04	Circularization burn cutoff	59.0	-10.9	169.1	-179.8	0.0	0.0	180.0	0.0	0.0	No line of sight		136.4	165.2			
73:40:00	Begin maneuver to landmark training photography attitude	59.0	-12.3	141.3	-152.6	0.0	0.0	180.0	0.0	0.0	No line of sight		136.4	165.2			2 deg/sec roll rate; 0.2 deg/sec pitch rate
73:47:11	Complete maneuver to landmark training photography attitude	58.8	-11.5	119.0	-62.0	0.0	180.0	-111.1	0.0	180.0	No line of sight		151.8	-157.0			Begin local hold
73:47:48	Acquire MSFN line of sight	58.8	-11.4	117.1	-62.0	0.0	180.0	-113.0	0.0	180.0	42.4	171.9	153.7	-156.5			Continue local hold
74:14:16	Begin manual pitch rate	58.0	2.8	37.3	-62.0	0.0	180.0	166.6	0.0	180.0	122.7	173.5	123.4	-12.2			Manual pitch rate
74:16:33	Terminate pitch rate; begin maneuver to IMU realignment attitude	58.0	4.2	30.5	-142.0	0.0	180.0	79.7	0.0	180.0	150.5	5.5	36.5	-12.2			-0.2 deg/sec pitch rate
74:22:53	Enter lunar umbra	57.9	7.4	11.4	-46.8	0.0	180.0	155.7	0.0	180.0	134.0	174.5	No line of sight				Continue pitch maneuver
74:26:00	Complete maneuver to IMU realignment attitude	57.8	9.2	1.9	0.0	0.0	180.0	-166.9	0.0	180.0	96.7	174.5	No line of sight				Begin inertial hold
74:30:00	IMU realignment	57.8	10.7	-10.9	12.1	0.0	180.0	-166.9	0.0	180.0	97.2	174.1	No line of sight				Continue inertial hold

Table II. Mission Apollo 8 Spacecraft Attitude Data
(c) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal Attitude			IMU Gimbal Angles			Look Angles To Earth		Look Angles To Sun		Look Angles To Landmark		Comments
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	
74:59:49	Lose MSFN line of sight	58.5	5.8	-102.3	102.4	0.0	180.0	-166.9	0.0	180.0	No line of sight		No line of sight				Continue inertial hold
75:00:00	Begin maneuver to orbital navigation photography attitude	58.4	5.8	-102.8	103.0	0.0	180.0	-166.9	0.0	180.0	No line of sight		No line of sight				0.2 deg/sec pitch rate
75:09:00	Enter sunlight	58.8	0.2	-129.7	22.3	0.0	180.0	84.7	0.0	180.0	No line of sight		41.7	-10.8			Continue pitch maneuver
75:15:23	Complete maneuver to orbital navigation photography attitude	58.9	-3.9	-148.7	-90.0	0.0	180.0	-46.9	0.0	180.0	No line of sight		89.6	-169.8			Begin local hold
75:46:00	Begin 180 deg roll; maintain orbital roll	58.8	-11.5	117.4	-90.0	0.0	180.0	-139.8	0.0	180.0	No line of sight		169.6	-76.7			2.0 deg/sec roll rate
75:46:11	Acquire MSFN line of sight	58.8	-11.4	116.4	-90.0	0.0	-158.0	-140.3	0.0	-158.0	70.6	152.3	169.4	-95.8			Continue roll maneuver
75:47:30	Complete 180 deg roll	58.7	-11.0	112.7	-90.0	0.0	0.0	-144.3	0.0	0.0	74.6	-5.6	167.7	124.2			Continue local hold
76:00:00	Begin maneuver to landmark evaluation attitude	58.3	-5.4	74.7	-90.0	0.0	0.0	177.8	0.0	0.0	112.5	-5.9	134.2	165.8			0.2 deg/sec pitch rate
76:05:39	Complete maneuver to landmark evaluation attitude	58.1	-1.9	57.8	-5.0	0.0	0.0	-114.4	0.0	0.0	44.9	-7.7	154.9	24.5			Begin local hold
76:21:29	Enter lunar umbra	57.9	7.8	10.4	-5.0	0.0	0.0	-162.5	0.0	0.0	93.3	-5.4	No line of sight				Continue local hold
76:28:00	Terminate local hold; begin 180 deg roll	57.9	10.5	-9.5	-5.0	0.0	0.0	177.7	0.0	0.0	113.1	-5.9	No line of sight				2.0 deg/sec roll rate
76:29:30	Complete 180 deg roll	57.8	11.0	-14.1	-0.5	0.0	180.0	177.7	0.0	180.0	113.2	174.1	No line of sight				Begin inertial hold
76:30:00	Begin IMU realignment	57.8	11.2	-15.7	1.1	0.0	180.0	177.7	0.0	180.0	113.2	174.1	No line of sight				Continue inertial hold
76:58:10	Lose MSFN line of sight	58.5	6.0	-102.5	86.6	0.0	180.0	177.7	0.0	180.0	No line of sight		No line of sight				Continue inertial hold
76:58:30	Begin maneuver to landmark sighting attitude	58.5	5.8	-103.5	87.6	0.0	180.0	177.7	0.0	180.0	No line of sight		No line of sight				2.0 deg/sec roll rate; 0.2 deg/sec pitch rate
77:07:35	Enter sunlight	58.8	0.2	-130.7	24.1	0.0	0.0	86.7	0.0	0.0	No line of sight		47.1	144.5			Continue maneuver
77:10:50	Complete maneuver to landmark sighting attitude	58.8	-1.9	-140.3	-5.0	0.0	0.0	47.7	0.0	0.0	No line of sight		11.6	135.7			Begin local hold
77:31:20	Begin pitch rate for 2nd control point landmark sighting	59.1	-11.7	157.6	-5.0	0.0	0.0	-14.4	0.0	0.0	No line of sight		54.5	12.3	55.4	155.0	-0.3 deg/sec pitch rate
77:33:37	Terminate pitch rate; begin maneuver to landmark sighting attitude	59.0	-12.1	150.5	-39.3	0.0	0.0	-55.5	0.0	0.0	No line of sight		98.6	10.2	101.6	164.1	0.2 deg/sec pitch rate
77:35:54	Complete maneuver to landmark sighting attitude	59.0	-12.3	143.5	-5.0	0.0	0.0	-28.2	0.0	0.0	No line of sight		71.3	10.7			Begin local hold
77:44:32	Acquire MSFN line of sight	58.8	-11.5	116.0	-5.0	0.0	0.0	-54.5	0.0	0.0	14.7	-158.2	97.1	10.2			Continue local hold
78:10:47	Begine pitch rate for pseudo landing site landmark sighting	58.0	2.3	37.3	-5.0	0.0	0.0	-134.2	0.0	0.0	66.0	-5.9	169.4	73.4	52.5	-177.5	-0.3 deg/sec pitch rate
78:13:05	Terminate pitch rate; begin 180 deg roll	58.0	3.8	30.5	-39.3	0.0	0.0	-175.4	0.0	0.0	107.1	-5.6	140.7	163.9	101.8	-178.6	2.0 deg/sec roll rate
78:14:35	Complete 180 deg roll	58.0	4.7	26.0	-34.8	0.0	180.0	-175.4	0.0	180.0	107.1	174.4	140.7	-16.1			Begin inertial hold
78:20:05	Enter lunar umbra	57.9	7.7	9.4	-18.1	0.0	180.0	-175.4	0.0	180.0	107.0	174.4	No line of sight				Continue inertial hold
78:30:00	Begin IMU realignment	57.9	11.5	-21.0	12.1	0.0	180.0	-175.4	0.0	180.0	107.5	174.4	No line of sight				Continue inertial hold
78:56:32	Lose MSFN line of sight	58.5	6.4	-103.0	92.7	0.0	180.0	-175.4	0.0	180.0	No line of sight		No line of sight				Continue inertial hold
78:58:30	Begin maneuver to landmark sighting attitude	58.5	5.0	-108.7	98.6	0.0	180.0	-175.4	0.0	180.0	No line of sight		No line of sight				2.0 deg/sec roll rate; -0.2 deg/sec pitch rate
79:06:12	Enter sunlight	58.7	0.2	-131.7	47.5	0.0	0.0	110.2	0.0	0.0	No line of sight		69.1	156.9			Continue maneuver
79:12:04	Complete maneuver to landmark sighting attitude	58.9	-3.6	-149.1	-5.0	0.0	0.0	39.8	0.0	0.0	No line of sight		10.5	74.6			Begin local hold
79:29:37	Begin pitch rate for 2nd control point landmark sighting	59.1	-11.6	157.6	-5.0	0.0	0.0	-13.4	0.0	0.0	No line of sight		56.8	12.1	55.4	155.9	-0.3 deg/sec pitch rate

Table II. Mission Apollo 8 Spacecraft Attitude Data
(c) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal Attitude			IMU Gimbal Angles			Look Angles To Earth		Look Angles To Sun		Look Angles To Landmark		Comments
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	
79:31:51	Terminate pitch rate; begin maneuver to landmark sighting attitude	59.0	-12.0	150.5	-39.3	0.0	0.0	-54.5	0.0	0.0	No line of sight		97.9	10.1	100.7	164.6	0.2 deg/sec pitch rate
79:34:08	Complete maneuver to landmark sighting attitude	59.0	-12.2	143.5	-5.0	0.0	0.0	-27.1	0.0	0.0	No line of sight		70.5	10.8			Begin local hold
79:42:30	Acquire MSFN line of sight	58.8	-11.6	117.6	-5.0	0.0	0.0	-52.5	0.0	0.0	15.6	-167.5	95.4	10.2			Continue local hold
80:09:03	Begin pitch rate for pseudo landing site landmark sighting	58.0	2.1	37.3	-5.0	0.0	0.0	-133.0	0.0	0.0	66.0	-5.8	169.1	68.4	52.0	-179.2	-0.3 deg/sec pitch rate
80:11:21	Terminate pitch rate; begin 180 deg roll	58.0	3.6	30.5	-39.3	0.0	0.0	-174.3	0.0	0.0	107.1	-5.6	141.7	163.5	101.6	-179.6	2.0 deg/sec roll rate
80:12:51	Complete 180 deg roll	57.9	4.5	26.0	-34.8	0.0	180.0	-174.3	0.0	180.0	107.1	174.4	141.7	-16.5			Begin inertial hold
80:18:41	Enter lunar umbra	57.9	7.8	8.4	-17.1	0.0	180.0	-174.3	0.0	180.0	107.2	174.4	No line of sight				Continue inertial hold
80:32:00	Begin IMU realignment	57.8	12.0	-32.7	23.5	0.0	180.0	-174.3	0.0	180.0	107.6	174.4	No line of sight				Continue inertial hold
80:54:50	Lose MSFN line of sight	58.5	6.5	-101.9	92.8	0.0	180.0	-174.3	0.0	180.0	No line of sight		No line of sight				Continue inertial hold
80:55:51	Begin maneuver to landmark sighting attitude	58.5	5.7	-106.0	95.8	0.0	180.0	-174.3	0.0	180.0	No line of sight		No line of sight				2.0 deg/sec roll rate; -0.2 deg/sec pitch rate
81:04:48	Enter sunlight	58.7	0.2	-132.7	33.5	0.0	0.0	96.3	0.0	0.0	No line of sight		54.8	156.6			Continue maneuver
81:09:06	Complete maneuver to landmark sighting attitude	58.9	-2.6	-145.5	-5.0	0.0	0.0	44.7	0.0	0.0	No line of sight		10.7	99.0			Begin local hold
81:14:00	Begin pitch rate for 1st control point landmark sighting	59.0	-5.6	-160.2	-5.0	0.0	0.0	29.7	0.0	0.0	No line of sight		16.6	38.1	52.3	166.5	-0.3 deg/sec pitch rate
81:16:18	Terminate pitch rate; begin maneuver to landmark sighting attitude	59.0	-6.9	-167.0	-39.3	0.0	0.0	-11.5	0.0	0.0	No line of sight		55.0	12.4	100.8	172.0	0.2 deg/sec pitch rate
81:18:35	Complete maneuver to landmark sighting attitude	59.0	-8.0	-174.0	-5.0	0.0	0.0	15.9	0.0	0.0	No line of sight		28.5	21.7			Begin local hold
81:27:54	Begin pitch rate for 2nd control point landmark sighting	59.0	-11.5	157.6	-5.0	0.0	0.0	-12.4	0.0	0.0	No line of sight		56.1	12.3	55.4	156.8	-0.3 deg/sec pitch rate
81:30:11	Terminate pitch rate; begin maneuver to landmark sighting attitude	59.0	-12.0	150.5	-39.3	0.0	0.0	-53.5	0.0	0.0	No line of sight		97.2	10.2	100.7	165.4	0.2 deg/sec pitch rate
81:32:28	Complete maneuver to landmark sighting attitude	59.0	-12.2	143.5	-5.0	0.0	0.0	-26.1	0.0	0.0	No line of sight		69.4	10.8			Begin local hold
81:40:51	Acquire MSFN line of sight	58.8	-11.6	117.2	-5.0	0.0	0.0	-51.7	0.0	0.0	15.8	-159.6	94.5	10.2			Continue local hold
81:46:59	Begin pitch rate for 3rd control point landmark sighting attitude	58.6	-9.8	98.4	-5.0	0.0	0.0	-70.3	0.0	0.0	6.5	-54.0	112.8	11.0	50.6	174.2	-0.3 deg/sec pitch rate
81:49:17	Terminate pitch rate; begin maneuver to landmark sighting attitude	58.6	-8.8	91.4	-39.3	0.0	0.0	-111.5	0.0	0.0	45.3	-7.4	152.6	22.5	100.7	176.6	0.2 deg/sec pitch rate
81:51:34	Complete maneuver to landmark sighting attitude	58.5	-7.5	84.4	-5.0	0.0	0.0	-84.1	0.0	0.0	19.4	-16.4	127.3	12.8			Begin local hold
82:07:19	Begin pitch rate for pseudo landing site sighting	58.0	1.9	37.3	-5.0	0.0	0.0	-132.0	0.0	0.0	66.0	-5.8	168.7	63.7	51.6	175.5	-0.3 deg/sec pitch rate
82:09:37	Terminate pitch rate;begin 180 deg roll	58.0	3.4	30.5	-39.3	0.0	0.0	-173.2	0.0	0.0	107.1	-5.5	142.6	163.1	101.4	177.3	2.0 deg/sec roll rate
82:11:07	Complete 180 deg roll	57.9	4.3	26.0	-34.8	0.0	180.0	-173.2	0.0	180.0	107.2	174.5	142.6	-16.9			Begin inertial hold
82:17:17	Enter lunar umbra	57.9	7.7	7.4	-16.0	0.0	180.0	-173.2	0.0	180.0	107.3	174.5	No line of sight				Continue inertial hold
82:25:00	Begin IMU realignment	57.8	10.9	-16.2	7.4	0.0	180.0	-173.2	0.0	180.0	107.5	174.5	No line of sight				Continue inertial hold
82:52:49	Lose MSFN line of sight	58.4	6.8	-102.1	92.4	0.0	180.0	-173.2	0.0	180.0	No line of sight		No line of sight				Continue inertial hold
82:54:07	Begin maneuver to landmark sighting attitude	58.4	5.9	-106.0	95.8	0.0	180.0	-173.2	0.0	180.0	No line of sight		No line of sight				2.0 deg/sec roll rate; -0.2 deg/sec pitch rate
83:03:24	Enter sunlight	58.8	0.2	-133.7	26.0	0.0	0.0	93.4	0.0	0.0	No line of sight		49.2	163.2			Continue maneuver

Table II. Mission Apollo 8 Spacecraft Attitude Data

(c) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal Attitude			IMU Gimbal Angles			Look Angles To Earth		Look Angles To Sun		Look Angles To Landmark		Comment
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	
83:07:22	Complete maneuver to landmark sighting attitude	58.9	-2.0	-144.5	-5.0	0.0	0.0	45.8	0.0	0.0	No line of sight		10.8	103.9			Begin local hold
83:12:17	Begin pitch rate for 1st control point landmark sighting	58.9	-5.4	-160.2	-5.0	0.0	0.0	30.8	0.0	0.0	No line of sight		15.8	40.3	51.7	169.4	-0.3 deg/sec pitch rate
83:14:34	Terminate pitch rate; begin maneuver to landmark sighting attitude	59.0	-6.7	-167.0	-39.3	0.0	0.0	-10.4	0.0	0.0	No line of sight		54.1	12.6	100.7	173.7	0.2 deg/sec pitch rate
83:16:51	Complete maneuver to landmark sighting attitude	59.0	-7.9	-174.0	-5.0	0.0	0.0	17.0	0.0	0.0	No line of sight		27.8	22.3			Begin local hold
83:26:10	Begin pitch rate for 2nd control point landmark sighting	59.1	-11.4	157.6	-5.0	0.0	0.0	-11.3	0.0	0.0	No line of sight		55.0	12.5	54.8	157.8	-0.3 deg/sec pitch rate
83:28:28	Terminate pitch rate; begin maneuver to landmark sighting attitude	59.1	-11.9	150.5	-39.3	0.0	0.0	-52.4	0.0	0.0	No line of sight		96.1	10.2	101.0	166.6	0.2 deg/sec pitch rate
83:30:45	Complete maneuver to landmark sighting attitude	59.0	-12.2	143.5	-5.0	0.0	0.0	-25.0	0.0	0.0	No line of sight		104.2	10.5			Begin local hold
83:39:13	Acquire MSFN line of sight	58.9	-11.7	116.9	-5.0	0.0	0.0	-51.8	0.0	0.0	15.0	-167.5	94.0	10.2			Continue local hold
83:45:16	Begin pitch rate for 3rd control point landmark sighting	58.7	-9.9	98.4	-5.0	0.0	0.0	-69.2	0.0	0.0	6.5	-53.5	111.8	10.9	50.6	172.2	-0.3 deg/sec pitch rate
83:47:34	Terminate pitch rate; begin maneuver to landmark sighting attitude	58.6	-8.9	91.4	-39.3	0.0	0.0	-110.4	0.0	0.0	45.4	-7.3	151.7	21.8	100.5	175.3	0.2 deg/sec pitch rate
83:49:51	Complete maneuver to landmark sighting attitude	58.5	-7.8	84.4	-5.0	0.0	0.0	-83.0	0.0	0.0	18.6	-16.8	125.5	12.5			Begin local hold
84:05:35	Begin pitch rate for pseudo landing site sighting	58.0	1.7	37.3	-5.0	0.0	0.0	-130.9	0.0	0.0	66.0	-5.7	168.2	59.2	51.2	173.9	-0.3 deg/sec pitch rate
84:07:53	Terminate pitch rate; begin 180 deg roll	58.0	3.2	30.5	-39.3	0.0	0.0	-172.1	0.0	0.0	107.1	-5.5	143.6	162.7	101.1	176.3	2.0 deg/sec roll rate
84:09:23	Complete 180 deg roll	58.0	4.1	26.0	-34.8	0.0	180.0	-172.1	0.0	180.0	107.2	174.5	143.6	-17.3			Begin inertial hold
84:15:54	Enter lunar umbra	57.9	7.8	6.4	-15.0	0.0	180.0	-172.1	0.0	180.0	107.3	174.5	No line of sight				Continue inertial hold
84:25:00	Begin IMU realignment	57.8	11.3	-21.6	12.7	0.0	180.0	-172.1	0.0	180.0	107.5	174.5	No line of sight				Continue inertial hold
84:45:00	Begin maneuver to darkside and solar corona photography attitude	58.2	9.7	-83.6	73.5	0.0	180.0	-172.1	0.0	180.0	107.8	174.6	No line of sight				-0.2 deg/sec pitch rate
84:51:14	Lose MSFN line of sight	58.4	6.8	-102.5	17.6	0.0	180.0	113.1	0.0	180.0	No line of sight		No line of sight				Continue maneuver
84:53:12	Complete maneuver to darkside and solar corona photography attitude	58.5	5.6	-108.4	0.0	0.0	180.0	89.6	0.0	180.0	No line of sight		No line of sight				Begin local hold
85:02:00	Enter sunlight; begin maneuver to orbital navigation photography attitude	58.8	0.1	-134.7	0.0	0.0	180.0	62.8	0.0	180.0	No line of sight		21.5	-22.3			0.5 deg/sec pitch rate
85:04:36	Complete maneuver to orbital navigation photography attitude	58.8	-1.5	-142.4	-70.0	0.0	180.0	-15.0	0.0	180.0	No line of sight		58.6	-168.1			Begin local hold
85:37:00	Begin pitch of 40 deg and roll to shade windows	58.8	-11.9	118.6	-70.0	0.0	180.0	-113.3	0.0	180.0	No line of sight		154.4	-156.0			2.0 deg/sec roll rate; 0.2 deg/sec pitch rate
85:37:06	Acquire MSFN line of sight	58.8	-11.9	118.3	-70.0	0.0	168.0	-113.6	0.0	168.0	154.4	-174.8	154.4	-144.0			Continue maneuver
85:42:28	Complete maneuver for orbital navigation photography	58.7	-10.4	101.7	-110.0	0.0	90.0	-169.8	0.0	90.0	105.5	-95.3	145.8	71.8			Begin local hold
86:14:30	Enter lunar umbra	57.9	7.8	5.4	-110.0	0.0	90.0	92.9	0.0	90.0	156.0	102.8	No line of sight				Continue local hold
86:16:00	Begin maneuver to IMU realignment attitude	57.8	8.5	0.8	-110.0	0.0	90.0	88.1	0.0	90.0	151.5	100.9	No line of sight				2.0 deg/sec roll rate; -0.2 deg/sec pitch rate
86:20:35	Complete maneuver to IMU realignment attitude	57.8	10.4	-13.2	-50.0	0.0	180.0	134.4	0.0	180.0	161.4	163.6	No line of sight				Begin inertial hold

Table II. Mission Apollo 8 Spacecraft Attitude Data
(c) Lunar Orbit (Continued)

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal Attitude			IMU Gimbal Angles			Look Angles To Earth		Look Angles To Sun		Look Angles To Landmark		Comment
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	
86:30:00	Begin IMU realignment	57.9	12.3	-42.4	-21.5	0.0	180.0	134.4	0.0	180.0	161.5	163.6	No line of sight				Continue inertial hold
86:49:35	Lose MSFN line of sight	58.4	6.8	-102.7	37.9	0.0	180.0	134.4	0.0	180.0	No line of sight		No line of sight				Continue inertial hold
86:50:00	Begin maneuver to lunar observation attitude	58.4	6.6	-104.0	39.2	0.0	180.0	134.4	0.0	180.0	No line of sight		No line of sight				0.2 deg/sec pitch rate
87:00:37	Enter sunlight	58.7	0.1	-135.7	-56.0	0.0	180.0	7.0	0.0	180.0	No line of sight		38.1	-157.1			Continue maneuver
87:04:25	Complete maneuver to lunar observation attitude	58.8	-2.3	-147.0	-90.0	0.0	180.0	-38.6	0.0	180.0	No line of sight		81.9	-169.5			Begin local hold
87:10:00	Begin maneuver to TEI burn attitude	59.0	-5.7	-163.7	-90.0	0.0	180.0	-55.5	0.0	180.0	No line of sight		98.6	-169.8			-0.2 deg/sec pitch rate
87:15:06	Complete maneuver to TEI burn attitude	59.1	-7.3	-178.8	-13.3	-3.8	179.0	5.7	-3.6	179.2	No line of sight		39.8	-158.5			Begin inertial hold
87:20:06	Begin maneuver to lunar observation attitude	59.1	-10.4	165.7	1.9	-3.8	179.2	5.7	-3.6	179.2	No line of sight		39.8	-158.5			0.2 deg/sec pitch rate
87:30:21	Complete maneuver to lunar observation attitude	59.0	-12.3	133.9	-90.0	0.0	180.0	-117.3	0.0	180.0	No line of sight		158.0	-151.8			Begin local hold
87:35:27	Acquire MSFN line of sight	58.8	-11.8	117.9	-90.0	0.0	180.0	-132.8	0.0	180.0	69.7	174.7	168.8	-111.2			Continue local hold
87:53:00	Terminate local attitude hold	58.3	-4.5	64.5	-90.0	0.0	180.0	174.0	0.0	180.0	122.8	173.9	130.1	-13.3			Begin inertial hold
88:13:05	Enter lunar umbra; begin IMU realignment	57.9	7.7	4.7	-29.3	0.0	180.0	174.0	0.0	180.0	123.3	173.9	No line of sight				Continue inertial hold
88:40:00	Begin maneuver to TEI burn attitude	58.2	10.5	-78.8	52.7	0.0	180.0	174.0	0.0	180.0	123.8	173.9	No line of sight				0.2 deg/sec pitch rate
88:47:53	Lose MSFN line of sight	58.4	7.0	-103.0	-18.0	0.0	180.0	79.4	0.0	180.0	No line of sight		No line of sight				Continue maneuver
88:54:02	Complete maneuver to TEI burn attitude	58.6	3.5	-121.2	-73.1	-3.8	179.2	5.7	-3.6	179.2	No line of sight		No line of sight				Begin inertial hold
88:59:12	Enter sunlight	58.7	0.1	-136.7	-57.3	-3.8	179.2	5.7	-3.6	179.2	No line of sight		39.8	-158.5			Continue inertial hold
89:15:07	Initiate TEI burn	59.0	-9.0	175.6	-11.0	-3.8	179.2	5.7	-3.6	179.2	No line of sight		39.8	-158.5			SPS Burn

Table II. Mission Apollo 8 Spacecraft Attitude Data
(d) Transearth

Mission Time (hr:min:sec)	Event	IMU Gimbal Angle IGA (deg)	IMU Gimbal Angle MGA (deg)	IMU Gimbal Angle OGA (deg)	Look Angle to Earth Theta (deg)	Look Angle to Earth Phi (deg)	Look Angle to Moon Theta (deg)	Look Angle to Moon Phi (deg)	Look Angle to Sun Theta (deg)	Look Angle to Sun Phi (deg)	Comments
89:18:33	TEI cutoff; orient for lunar surface acquisition	-87.0	0.3	178.7	No Line of Sight		0.0	179.2	129.4	-165.2	+X axis down, +Z axis forward; inertial hold
90:00:00	Orient for IMU fine alignment	-87.0	0.3	178.7	25.2	169.2	87.2	0.0	129.4	-165.2	0.5 deg/sec maneuver rate;* change to entry REFSMMAT
90:10:00	Perform IMU fine alignment	90.1	-4.2	2.1	25.2	169.1	92.2	0.0	129.4	-165.2	Begin inertial hold
90:30:00	Complete IMU fine alignment; orient for navigation sightings	90.1	-4.2	2.1	25.2	169.1	98.5	0.0	129.5	-165.2	0.5 deg/sec maneuver rate
90:40:00	Perform SLH navigation sightings	133.3	-1.6	-175.6	68.0	-5.0	57.5	180.0	166.9	61.0	Begin local hold
92:00:00	Complete navigation sightings; orient for PTC	142.2	-0.9	-175.4	77.0	-4.7	57.5	180.0	168.3	102.9	0.5 deg/sec maneuver rate
92:10:00	Start PTC	-155.4	-20.0	5.0	135.4	-163.2	23.9	97.4	108.5	-23.7	Roll at 0.1 deg/sec
95:55:00	Complete PTC; orient for IMU realignment	-155.4	-20.0	-85.0	135.7	-73.0	23.7	173.6	108.3	66.4	0.5 deg/sec maneuver rate*
96:05:00	Perform IMU realignment	-155.4	-20.0	-85.0	135.7	-73.0	23.7	173.3	108.3	66.4	Begin inertial hold
96:25:00	Complete IMU realignment; orient for PTC	-155.4	-20.0	-85.0	135.7	-73.0	23.7	172.8	108.3	66.4	0.5 deg/sec maneuver rate
96:35:00	Start PTC	-155.4	-20.0	5.0	135.7	-163.0	23.7	82.6	108.3	-23.6	Roll at 0.1 deg/sec
99:50:00	Complete PTC; orient for IMU realignment	-155.4	-20.0	95.0	136.1	107.3	23.9	-10.9	108.2	-113.6	0.5 deg/sec maneuver rate*
100:00:00	Perform IMU realignment	-155.4	-20.0	95.0	136.1	107.3	23.9	-11.1	108.2	-113.6	Begin inertial hold
100:20:00	Complete IMU realignment; orient for navigation sightings	-155.4	-20.0	95.0	136.1	107.3	23.9	-11.3	108.2	-113.5	0.5 deg/sec maneuver rate
100:30:00	Perform SLH navigation sightings	149.6	2.0	-176.8	85.2	-2.9	57.5	180.0	166.1	140.3	Begin local hold
101:20:00	Complete SLH navigation sightings; orient for SEH navigation sightings	149.8	-2.0	-176.8	85.5	-3.0	57.5	180.0	165.9	140.9	0.5 deg/sec maneuver rate
101:30:00	Perform SEH navigation sightings	121.8	-0.4	-0.2	57.5	180.0	85.7	4.0	160.5	-146.3	Begin local hold
102:30:00	Complete navigation sightings; orient for IMU realignment	121.7	-0.4	-0.2	57.5	180.0	86.1	4.0	160.4	-146.6	0.5 deg/sec maneuver rate
102:40:00	Perform IMU realignment	121.7	-0.4	-90.2	57.5	-90.0	86.1	94.0	160.4	-56.7	Roll 90 deg for thermal control; begin inertial hold

*Maneuver not simulated

Table II. Mission Apollo 8 Spacecraft Attitude Data
(d) Transearth (Continued)

Mission Time (hr:min:sec)	Event	IMU Gimbal Angle IGA (deg)	IMU Gimbal Angle MGA (deg)	IMU Gimbal Angle OGA (deg)	Look Angle to Earth Theta (deg)	Look Angle to Earth Phi (deg)	Look Angle to Moon Theta (deg)	Look Angle to Moon Phi (deg)	Look Angle to Sun Theta (deg)	Look Angle to Sun Phi (deg)	Comments
103:00:00	Complete IMU realignment; roll 180 deg	121.7	-0.4	-90.2	57.5	-90.0	86.2	94.0	160.4	-56.7	0.5 deg/sec maneuver rate
103:30:00	Orient for MCC	121.7	-0.4	89.8	57.6	90.0	86.3	-86.0	160.5	123.4	Maneuver to burn attitude
104:00:00	Initiate midcourse correction	154.0	0.0	0.0	90.0	180.0	54.1	4.6	161.3	-33.5	In-plane, local horizontal attitude
104:30:00	Roll 180 deg for thermal control	154.0	0.0	180.0	90.0	0.0	54.2	-175.4	161.2	146.6	In-plane, local horizontal attitude
105:00:00	Orient for navigation sightings	154.0	0.0	180.0	90.1	0.0	54.3	-175.4	161.2	146.6	0.5 deg/sec maneuver rate
105:10:00	Perform SEH navigation sightings	121.3	-0.2	-0.1	57.5	180.0	87.0	3.9	160.3	-147.4	Begin local hold
106:00:00	Complete SEH navigation sightings; orient for SLH navigation sightings	121.2	-0.2	-0.0	57.5	180.0	87.2	3.9	160.2	-147.6	0.5 deg/sec maneuver rate
106:10:00	Perform SLH navigation sightings	150.9	2.0	-176.8	87.2	-3.0	57.5	180.0	164.9	143.6	Begin local hold
106:40:00	Complete navigation sightings	150.9	2.0	-176.8	87.4	-3.0	57.5	180.0	164.8	143.7	Continue local hold
107:20:00	Orient for IMU realignment	150.9	2.0	-176.8	87.5	-3.0	57.6	180.0	164.8	143.7	0.5 deg/sec maneuver rate*
107:30:00	Perform IMU realignment	150.9	2.0	-176.8	87.5	-2.9	57.6	180.0	164.8	143.7	Begin inertial hold
107:50:00	Complete IMU realignment; orient for SEH navigation sightings	150.9	2.0	-176.8	87.6	-2.9	57.7	180.0	164.7	143.6	0.5 deg/sec maneuver rate
108:00:00	Perform SEH navigation sightings	120.9	-0.2	0.0	57.5	180.0	87.9	3.8	160.1	-148.1	Begin local hold
108:50:00	Complete navigation sightings; orient for PTC	120.7	-0.2	0.0	57.5	180.0	88.1	3.8	160.0	-148.3	0.5 deg/sec maneuver rate
109:00:00	Start PTC	17.9	30.0	-0.1	52.5	-26.3	144.6	109.3	70.2	-154.8	Roll at 0.1 deg/sec
114:50:00	Complete PTC; orient for IMU realignment	17.9	30.0	-60.1	51.7	32.9	144.4	170.7	70.4	-94.9	0.5 deg/sec maneuver rate*
115:00:00	Perform IMU realignment	17.9	30.0	-60.1	51.6	32.9	144.4	170.7	70.4	-94.9	Begin inertial hold
115:20:00	Complete IMU realignment; orient for PTC	17.9	30.0	-60.1	51.6	32.8	144.4	170.8	70.4	-94.9	0.5 deg/sec maneuver rate
115:30:00	Start PTC	17.9	30.0	-0.1	51.6	-27.2	144.4	110.8	70.4	-154.9	Roll at 0.1 deg/sec
120:00:00	Complete PTC; orient for navigation sightings	17.9	30.0	179.9	50.7	151.9	144.2	-68.1	70.6	24.9	0.5 deg/sec maneuver rate
120:10:00	Perform SEH navigation sightings	118.4	0.0	0.0	57.5	180.0	92.1	3.7	158.4	-151.1	Begin local hold
120:30:00	Complete navigation sightings	118.2	0.0	0.0	57.5	180.0	92.3	3.7	158.3	-151.3	Continue local hold
121:00:00	Orient for IMU realignment	118.2	0.0	0.0	57.5	180.0	92.6	3.7	158.2	-151.4	0.5 deg/sec maneuver rate
121:10:00	Perform IMU realignment	118.2	0.0	0.0	57.5	180.0	92.6	3.7	158.2	-151.4	Begin inertial hold
121:30:00	Complete IMU realign; orient for MCC	118.2	0.0	0.0	57.6	180.0	92.6	3.7	158.2	-151.4	Maneuver to burn attitude
122:00:00	Initiate midcourse correction	150.4	0.0	0.0	90.0	180.0	60.5	4.2	163.6	-38.7	In-plane, local horizontal attitude
122:30:00	Perform SLH navigation sightings	153.3	2.0	-176.9	93.1	-3.2	57.5	180.0	162.2	148.8	Begin local hold
123:00:00	Complete navigation sightings	153.4	2.0	-176.9	93.3	-3.2	57.5	180.0	162.1	149.0	Continue local hold
123:20:00	Orient for navigation sightings	153.4	2.0	-176.9	93.4	-3.2	57.6	180.0	162.1	149.0	0.5 deg/sec maneuver rate

*maneuver not simulated

Table II. Mission Apollo 8 Spacecraft Attitude Data
(d) Transearth (Continued)

Mission Time (hr:min:sec)	Event	IMU Gimbal Angle IGA (deg)	IMU Gimbal Angle MGA (deg)	IMU Gimbal Angle OGA (deg)	Look Angle to Earth Theta (deg)	Look Angle to Earth Phi (deg)	Look Angle to Moon Theta (deg)	Look Angle to Moon Phi (deg)	Look Angle to Sun Theta (deg)	Look Angle to Sun Phi (deg)	Comments
123:30:00	Perform SEH navigation sightings	117.4	0.0	0.0	57.5	180.0	93.6	3.7	157.7	-152.2	Begin local hold
124:20:00	Complete navigation sightings; orient for PTC	117.1	0.0	0.0	57.5	180.0	94.0	3.6	157.5	-152.4	0.5 deg/sec maneuver rate
124:30:00	Start PTC	17.9	30.0	-0.1	49.7	-29.3	144.0	113.1	70.7	-155.2	Roll at 0.1 deg/sec
129:20:00	Complete PTC; orient for IMU realignment	17.9	30.0	-60.1	48.3	29.1	143.8	174.5	70.9	-95.3	0.5 deg/sec maneuver rate*
129:30:00	Perform IMU realignment	17.9	30.0	-60.1	48.2	29.0	143.8	174.5	70.9	-95.3	Begin inertial hold
129:50:00	Complete IMU realignment; orient for navigation sightings	17.9	30.0	-60.1	48.1	28.9	143.8	174.6	70.9	-95.3	0.5 deg/sec maneuver rate
130:00:00	Perform SLH navigation sightings	154.6	1.9	-177.0	97.2	-3.2	57.5	180.0	160.7	150.9	Begin local hold
130:30:00	Complete SLH navigation sightings; orient for SEH navigation sightings	154.7	1.9	-177.0	97.5	-3.2	57.5	180.0	160.6	151.0	0.5 deg/sec maneuver rate
130:40:00	Perform SEH navigation sightings	114.5	0.0	0.0	57.5	180.0	97.9	3.6	155.3	-155.0	Begin local hold
131:50:00	Complete navigation sightings; orient for PTC	113.9	0.0	0.0	57.5	180.0	98.6	3.5	154.9	-155.4	0.5 deg/sec maneuver rate
132:00:00	Start PTC	17.9	30.0	0.0	47.3	-32.2	143.7	113.3	71.0	-155.4	Roll at 0.1 deg/sec
135:15:00	Complete PTC; orient for IMU realignment	17.9	30.0	90.0	45.7	-124.3	143.5	26.4	71.1	114.5	0.5 deg/sec maneuver rate*
135:25:00	Perform IMU realignment	17.9	30.0	90.0	45.6	-124.4	143.5	26.3	71.1	114.5	Begin inertial hold
135:45:00	Complete IMU realignment; orient for PTC	17.9	30.0	90.0	45.4	-124.7	143.4	26.6	71.1	114.5	0.5 deg/sec maneuver rate
135:55:00	Start PTC	17.9	30.0	0.0	45.3	-34.8	143.4	116.7	71.1	-155.5	Roll at 0.1 deg/sec
139:10:00	Complete PTC; orient for IMU realignment	17.9	30.0	90.0	42.8	-128.5	143.2	28.0	71.2	114.4	0.5 deg/sec maneuver rate*
139:20:00	Perform IMU realignment	17.9	30.0	90.0	42.7	-128.8	143.2	28.1	71.2	114.4	Begin inertial hold
139:40:00	Complete IMU realignment; orient for PTC	17.9	30.0	90.0	42.3	-129.3	143.2	28.2	71.2	114.4	0.5 deg/sec maneuver rate
139:50:00	Start PTC	17.9	35.0	0.0	45.5	-43.6	138.7	115.4	73.4	-154.3	Roll at 0.1 deg/sec
143:40:00	Complete PTC; orient for IMU realignment	17.9	35.0	-60.0	40.0	3.4	138.4	177.0	73.5	-94.4	0.5 deg/sec maneuver rate*
143:50:00	Perform IMU realignment	17.9	35.0	-60.0	39.7	2.3	138.4	177.1	73.5	-94.4	Begin inertial hold
144:10:00	Complete IMU align; orient for MCC	17.9	35.0	-60.0	38.9	-0.4	138.4	177.4	73.5	-94.4	Maneuver to burn attitude

*maneuver not simulated

Table II. Mission Apollo 8 Spacecraft Attitude Data
(d) Transearth (Continued)

Mission Time (hr:min:sec)	Event	IMU Gimbal Angle			Look Angle to Earth		Look Angle to Moon		Look Angle to Sun		Comments
		IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	
144:50:00	Initiate midcourse correction	121.0	0.0	0.0	90.0	180.0	94.9	3.0	161.6	-146.2	In-plane, local horizontal attitude
145:30:00	Orient for IMU realignment	121.0	0.0	0.0	98.3	180.0	95.0	3.0	161.6	-146.1	0.5 deg/sec maneuver rate
145:40:00	Perform IMU realignment	156.0	0.0	0.0	136.4	180.0	60.1	3.4	158.0	-28.1	Performed in entry attitude; begin inertial hold
146:00:00	Complete IMU realignment	156.0	0.0	0.0	144.2	180.0	60.1	3.4	158.0	-28.1	Continue inertial hold
146:32:30	Orient for CM/SM separation	-90.0	45.0	0.0	72.9	-17.9	63.3	-154.9	69.2	-40.3	Yaw 45 deg
146:34:30	CM/SM separation; orient for entry	-90.0	45.0	0.0	69.8	-21.6	63.4	-154.9	69.2	-40.3	
146:49:30	Entry	156.0	0.0	0.0	114.0	0.0	59.1	3.3	158.0	-28.0	In-plane, retrograde, heads down attitude

Table III. Mission Apollo 8 IMU Matrices; Launch Date December 21, 1968; 72 Degrees Launch Azimuth

Pre-Launch REFSMMAT

$$\begin{bmatrix} \overline{X} \\ \overline{Y} \\ \overline{Z} \end{bmatrix} = \begin{bmatrix} \underline{X} & \underline{Y} & \underline{Z} \\ 0.49747632 & -0.30486110 & 0.81214345 \\ -0.82399864 & -0.45874424 & 0.33253554 \\ 0.27118897 & -0.83463369 & -0.47941956 \end{bmatrix}$$

LOI-2 REFSMMAT

$$\begin{bmatrix} \overline{X} \\ \overline{Y} \\ \overline{Z} \end{bmatrix} = \begin{bmatrix} \underline{X} & \underline{Y} & \underline{Z} \\ -0.64877632 & 0.07638412 & -0.7571359 \\ -0.66111865 & -0.54928435 & 0.51108595 \\ -0.37684405 & 0.83213712 & 0.40686164 \end{bmatrix}$$

Entry REFSMMAT

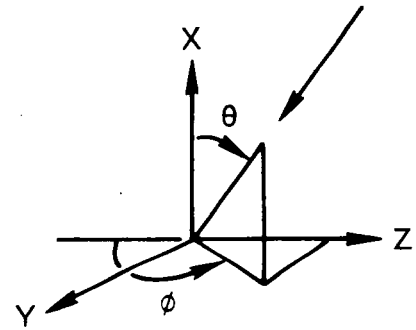
$$\begin{bmatrix} \overline{X} \\ \overline{Y} \\ \overline{Z} \end{bmatrix} = \begin{bmatrix} \underline{X} & \underline{Y} & \underline{Z} \\ -0.60992761 & 0.01410319 & 0.79233164 \\ -0.65428522 & 0.55514414 & -0.51354244 \\ -0.44710085 & -0.83163459 & -0.32937023 \end{bmatrix}$$

Table IV. Scanning Telescope Sighting Targets

Launch Date: December 21, 1968

Landing Site: II-P-2

Type	Latitude	Longitude	Altitude (meters)
First control point landmark	5.250° S	162.700° W	0.0
Second control point landmark	10.200° S	155.100° E	0.0
Third control point landmark	9.100° S	95.900° E	0.0
Pseudo landing site landmark	2.675° N	35.025° E	-890.0



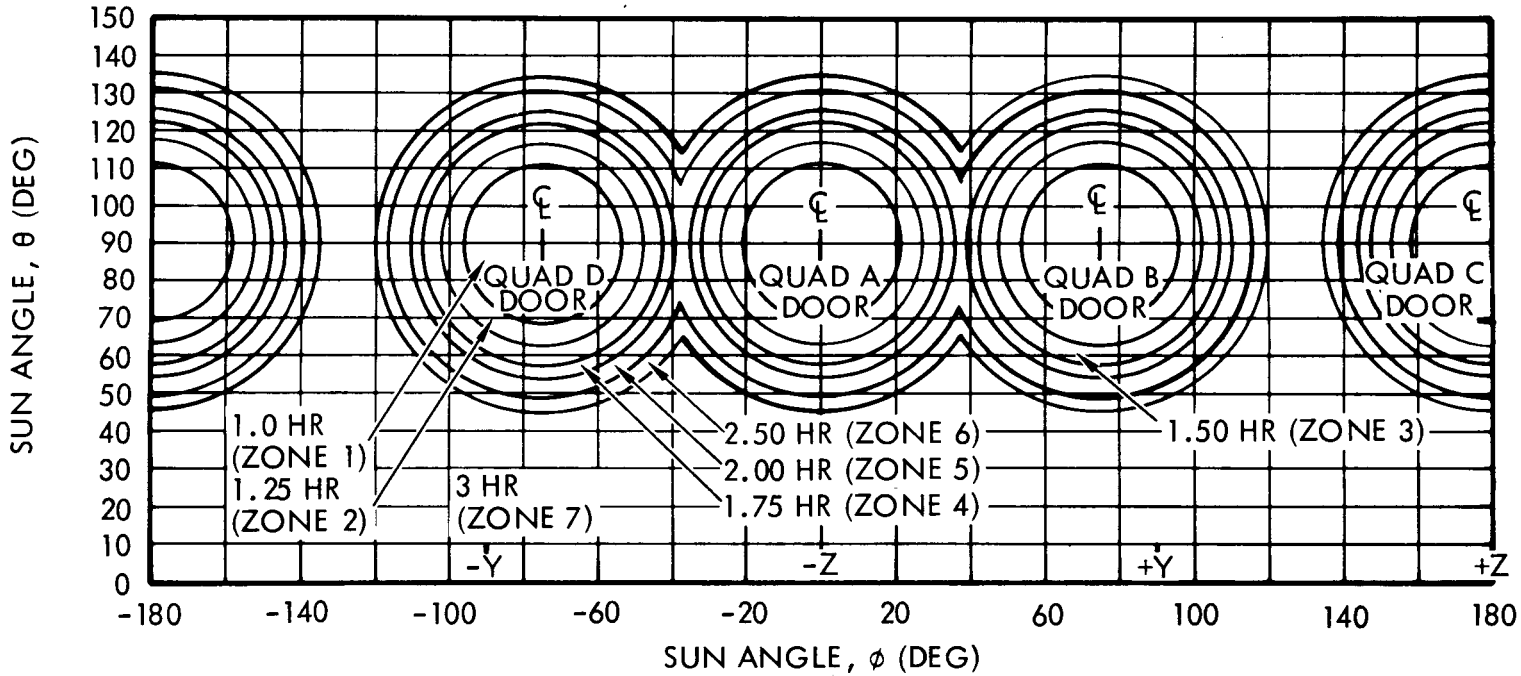


Figure 1. RCS Quads Fracture Mechanics Attitude Hold Limits

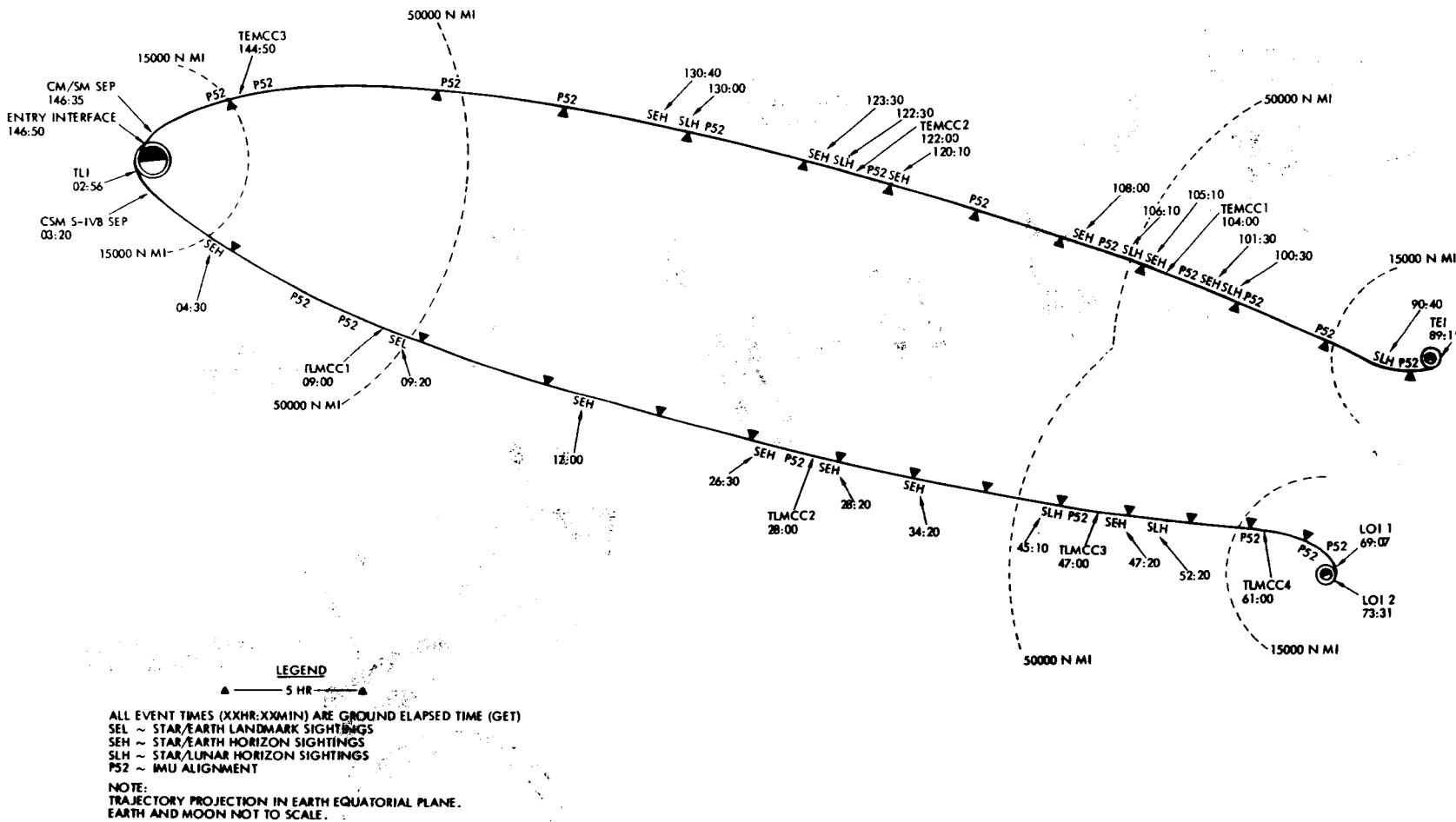


Figure 2. Mission Apollo 8 Cislunar Trajectory and Event Profile

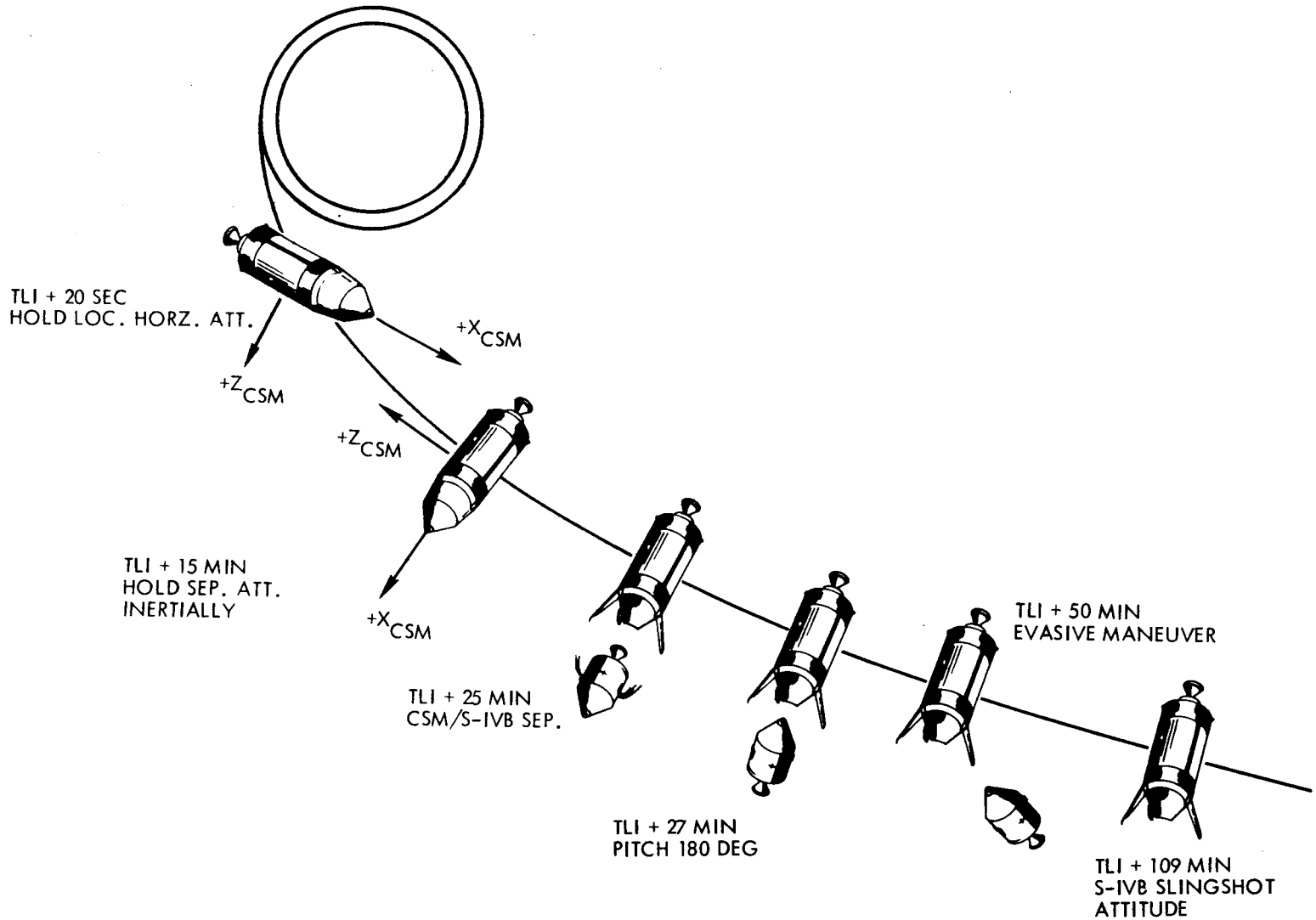


Figure 3. Mission Apollo 8 Post-TLI Sequence of Events

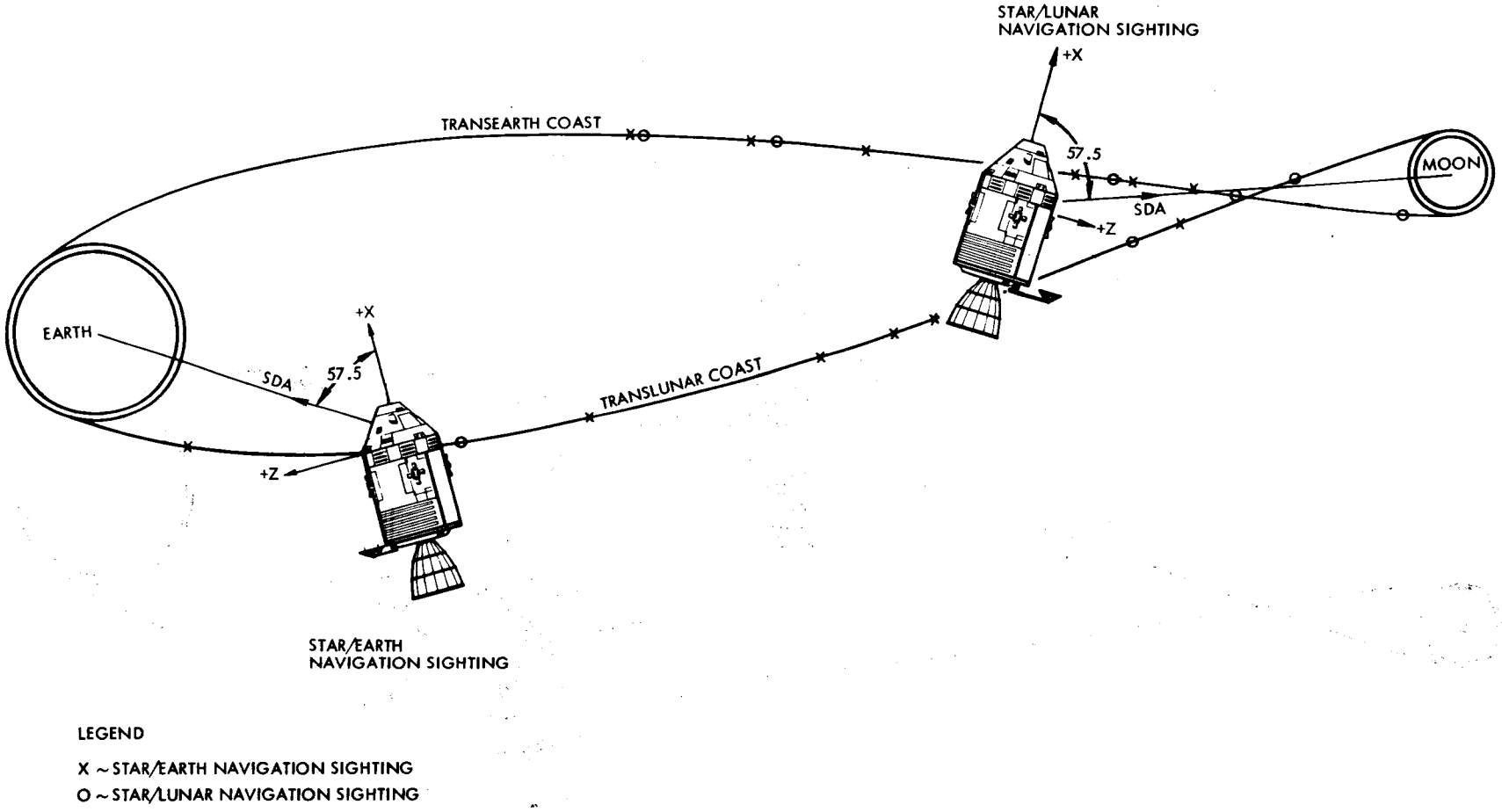


Figure 4. Cislunar Navigation Sighting Attitude Geometry

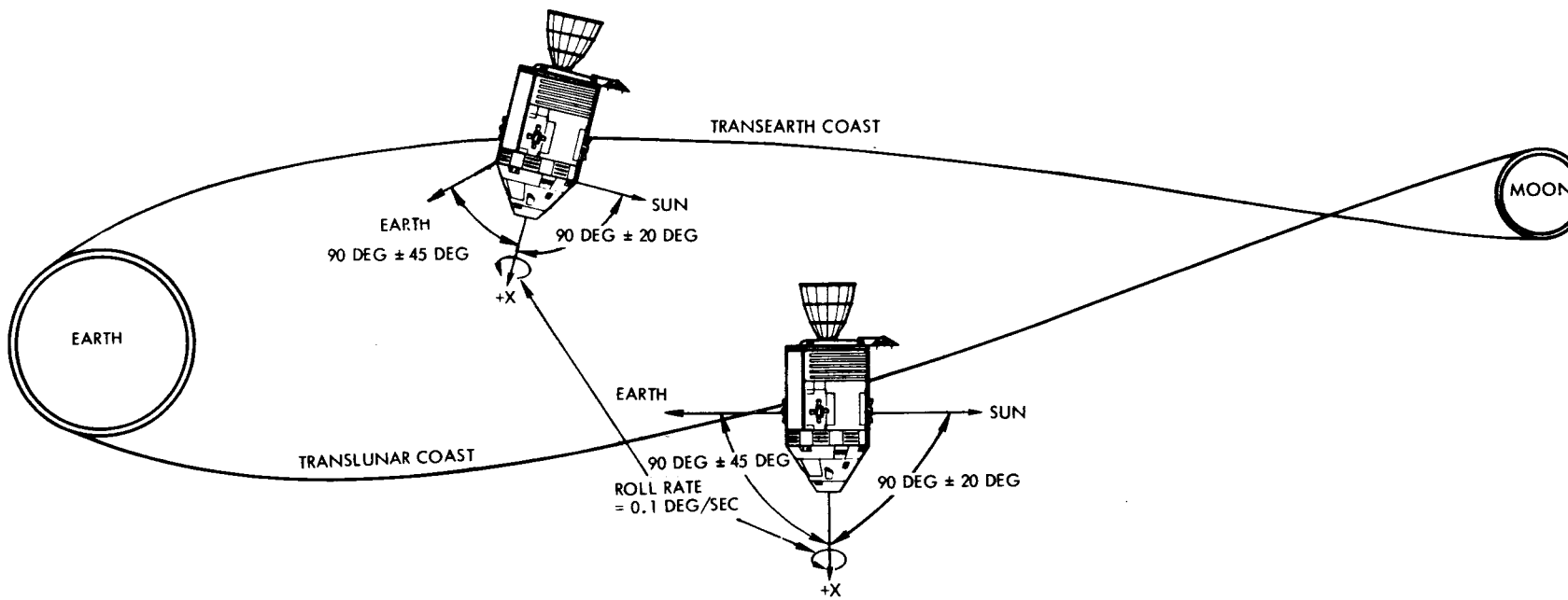


Figure 5. PTC Attitude Geometry

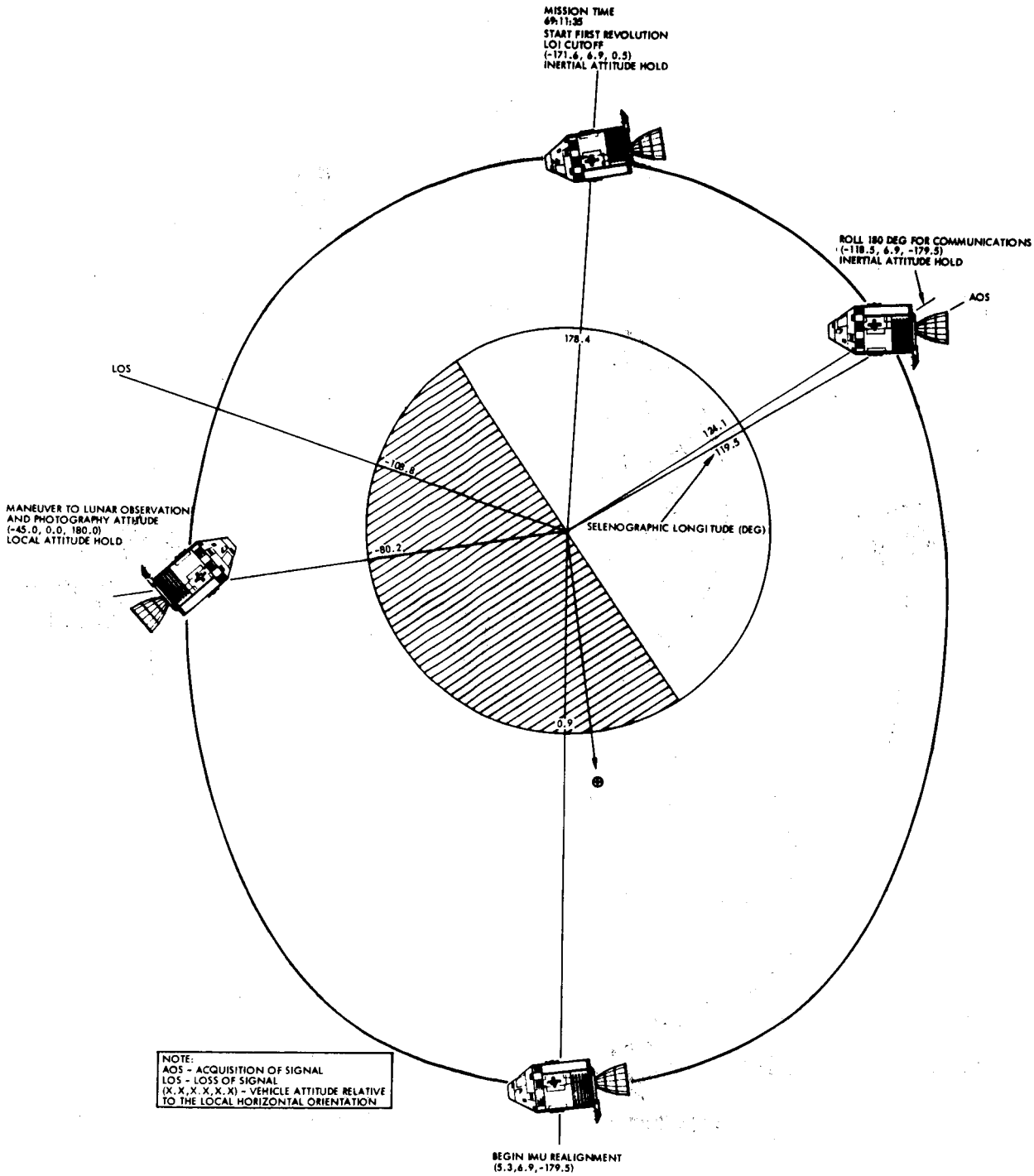


Figure 6. First Revolution Major Events and Attitudes

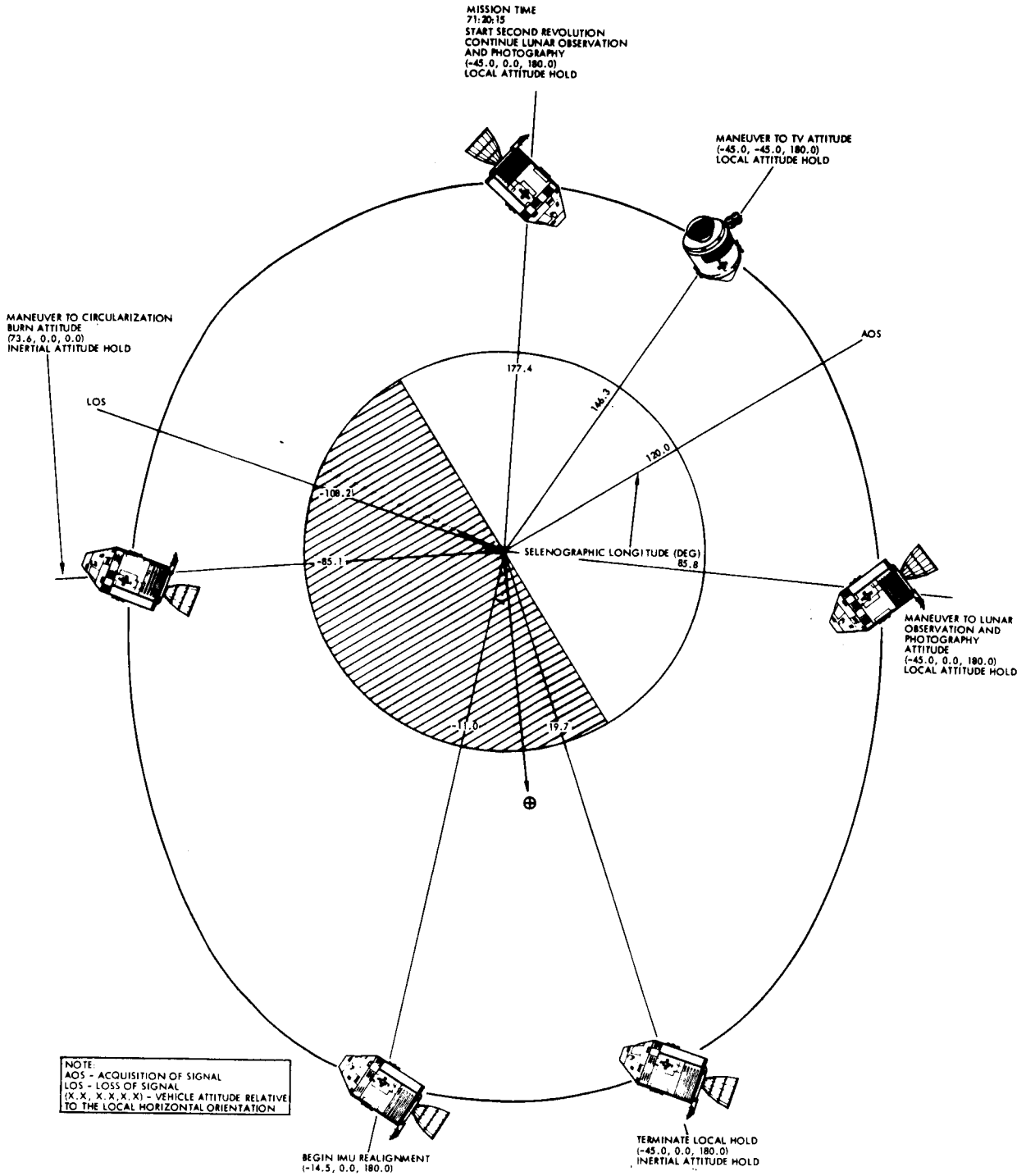


Figure 7. Second Revolution Major Events and Attitudes

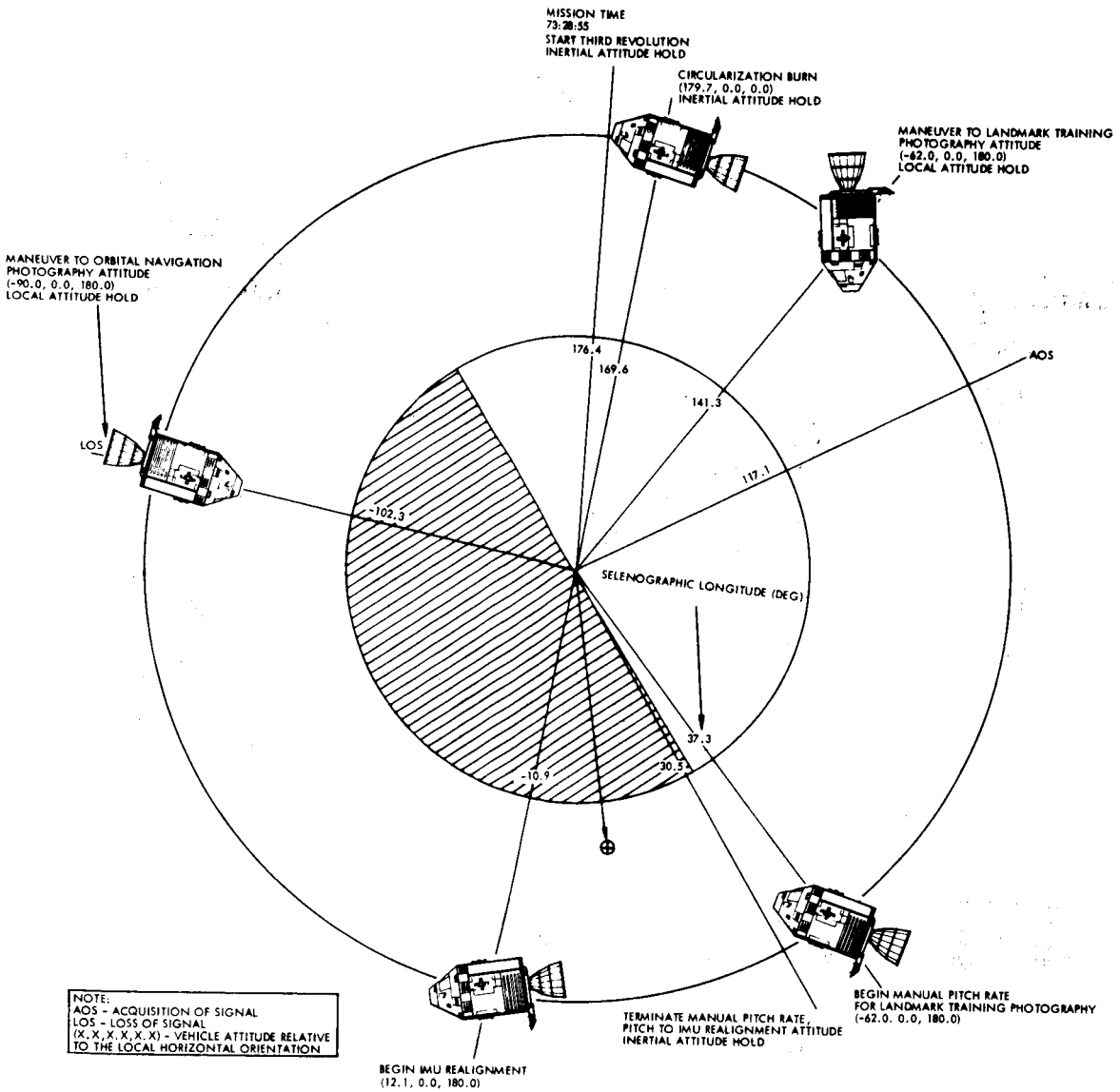


Figure 8. Third Revolution Major Events and Attitudes

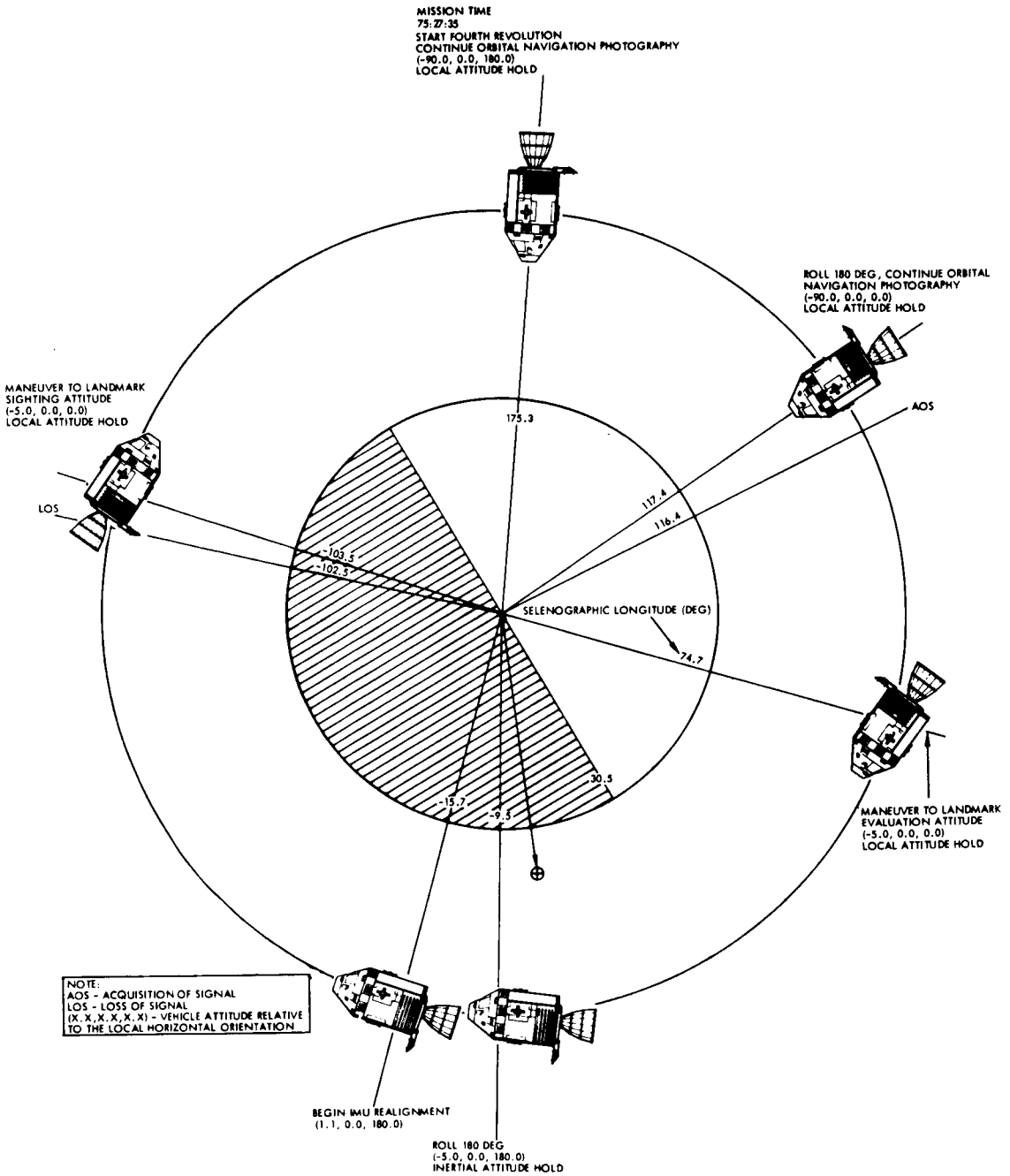


Figure 9. Fourth Revolution Major Events and Attitudes

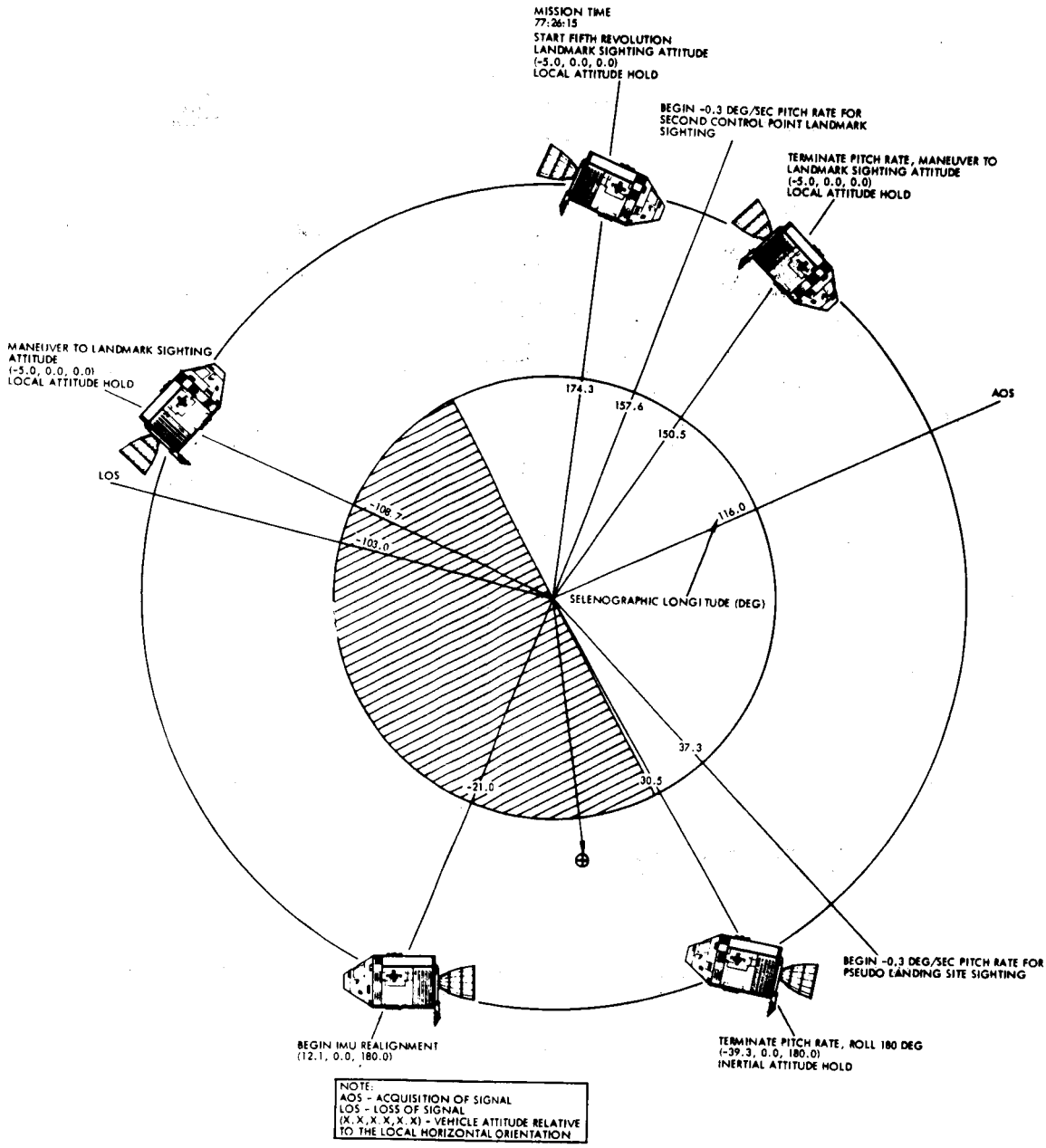


Figure 10. Fifth Revolution Major Events and Attitudes

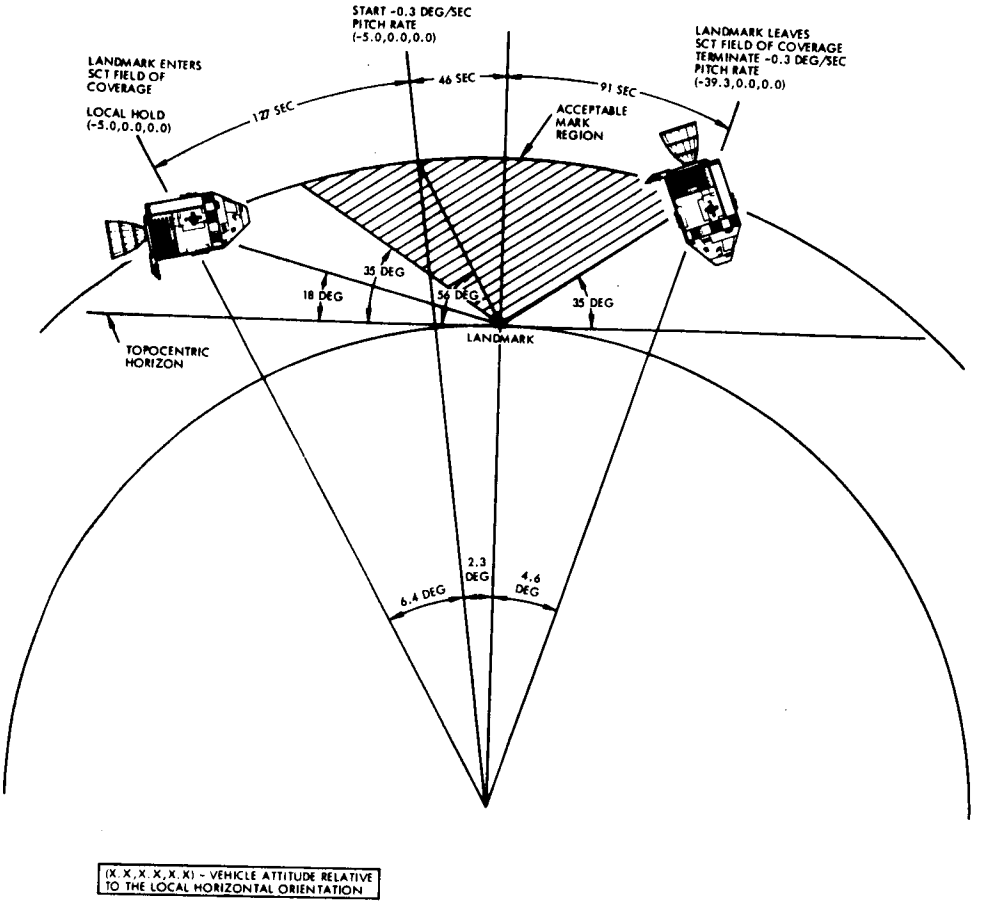


Figure 11. Mode III Type Landmark Sighting Attitude Sequence

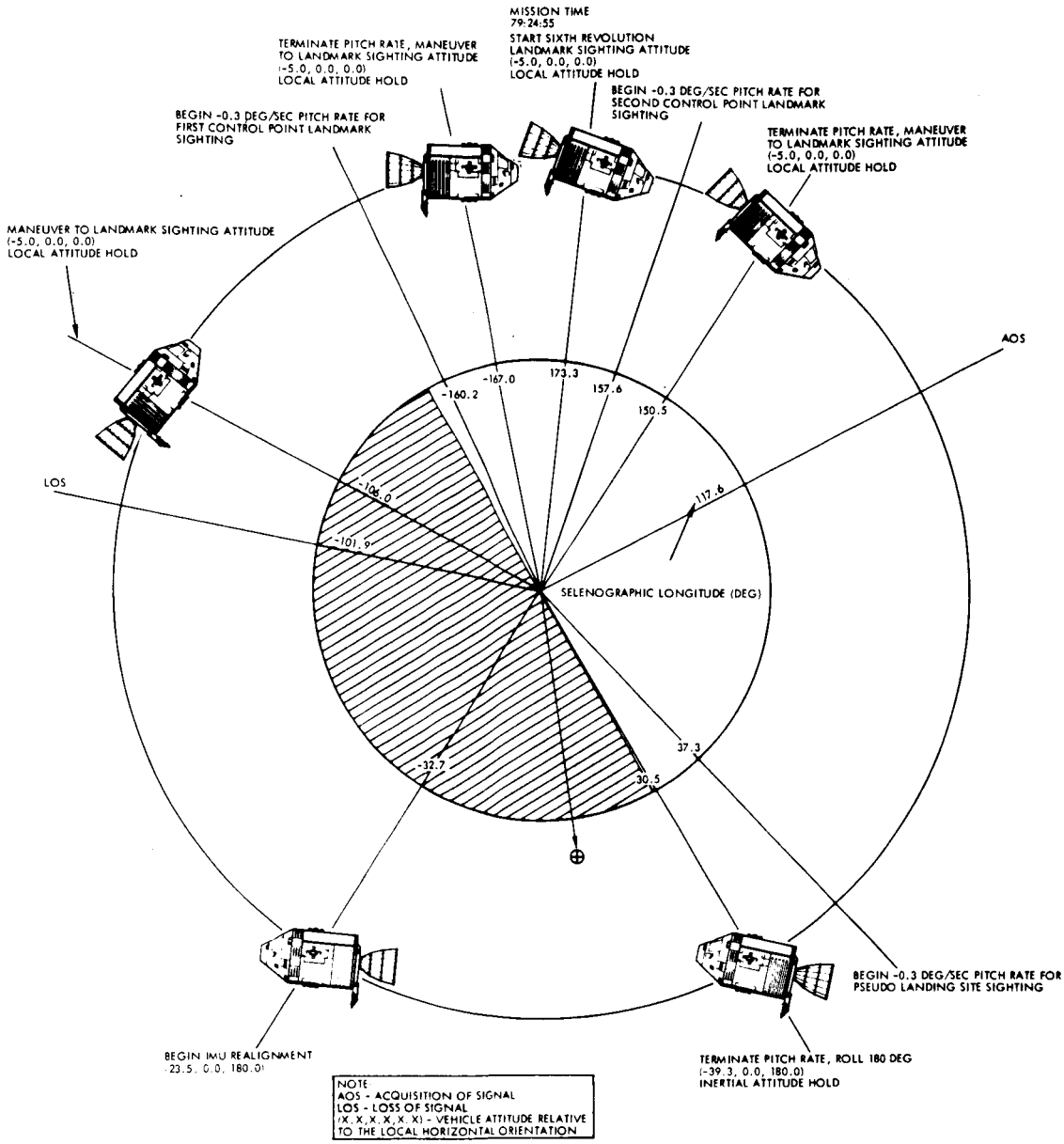


Figure 12. Sixth Revolution Major Events and Attitudes

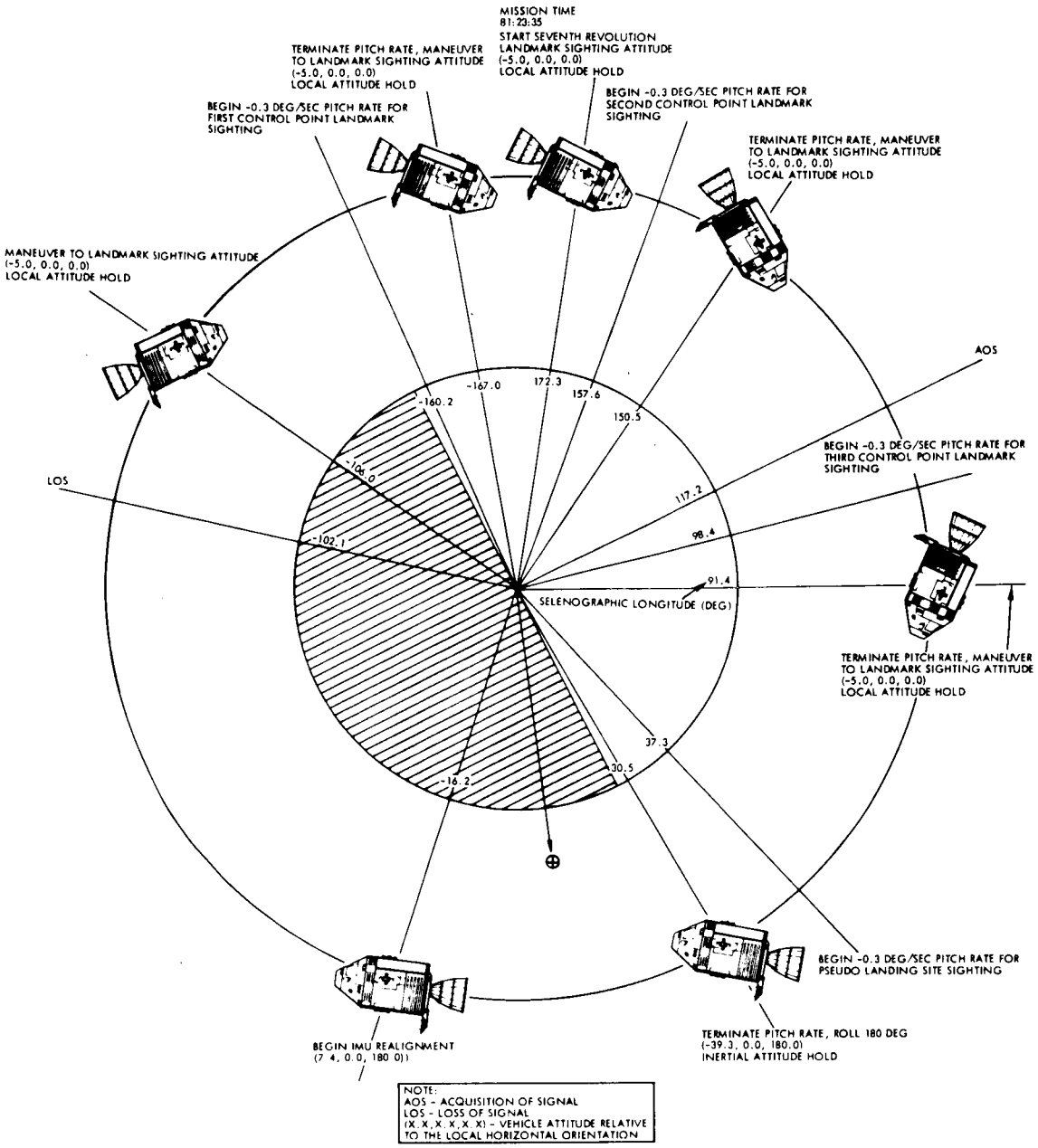


Figure 13. Seventh Revolution Major Events and Attitudes

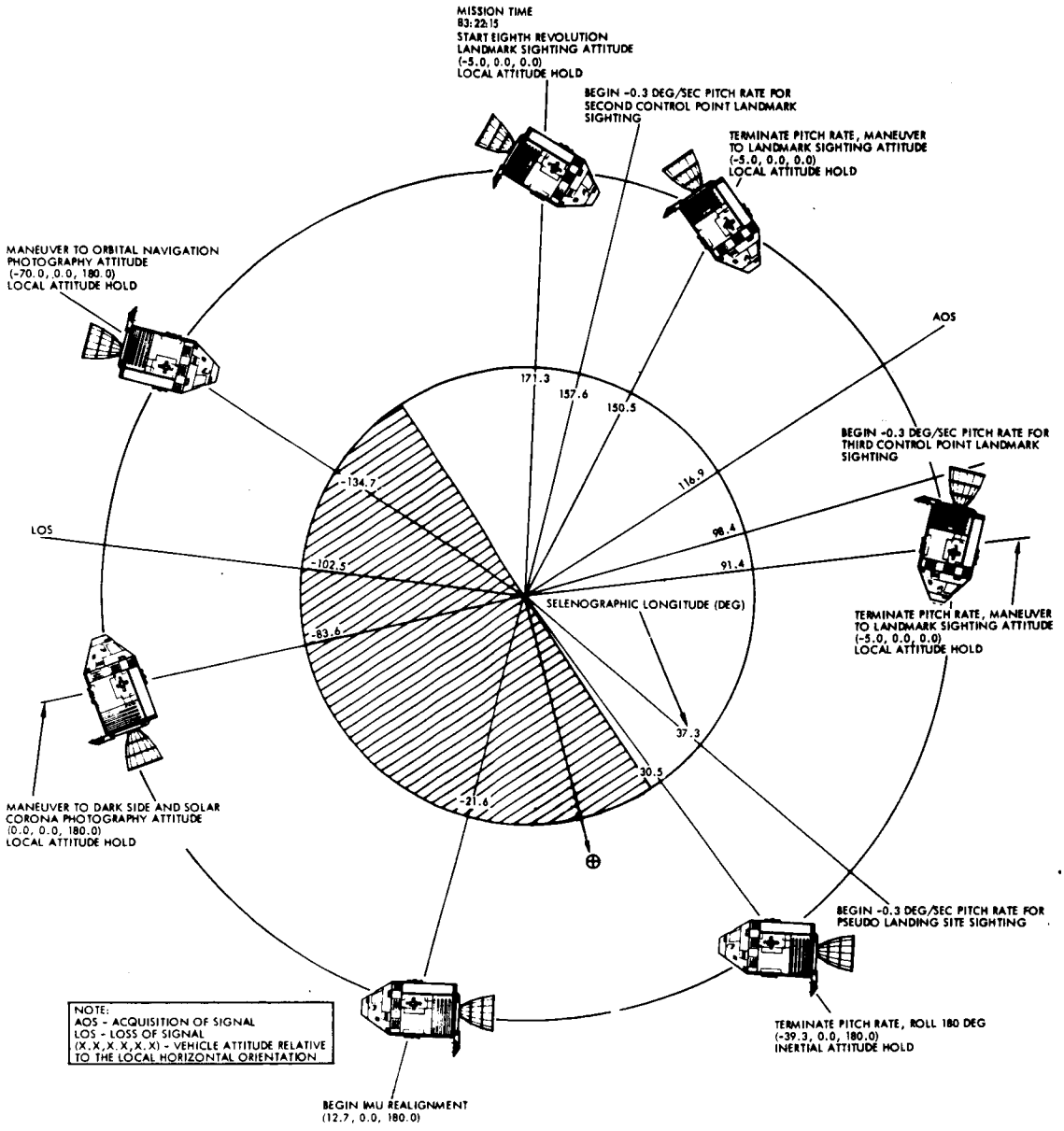


Figure 14. Eighth Revolution Major Events and Attitudes

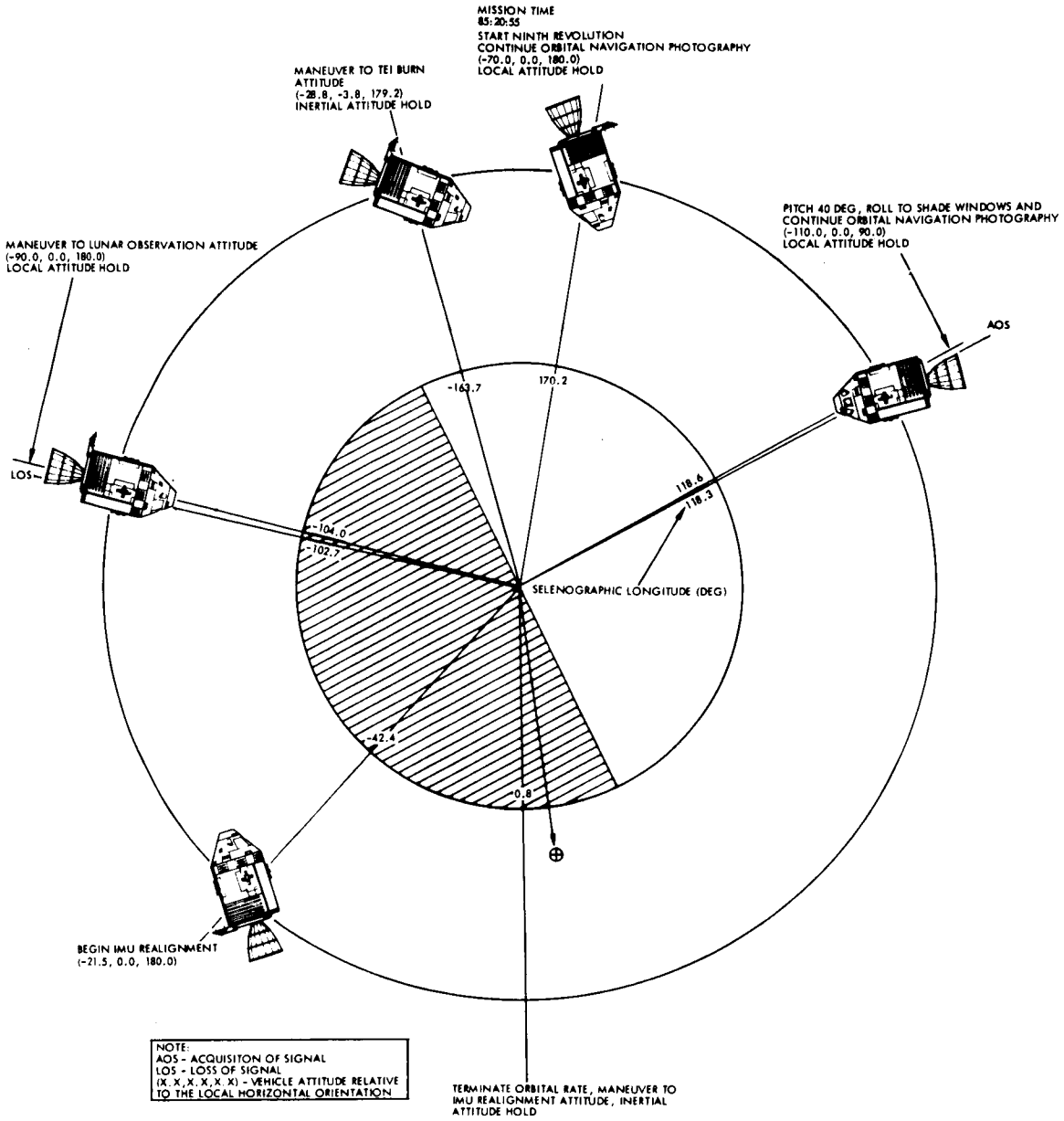


Figure 15. Ninth Revolution Major Events and Attitudes

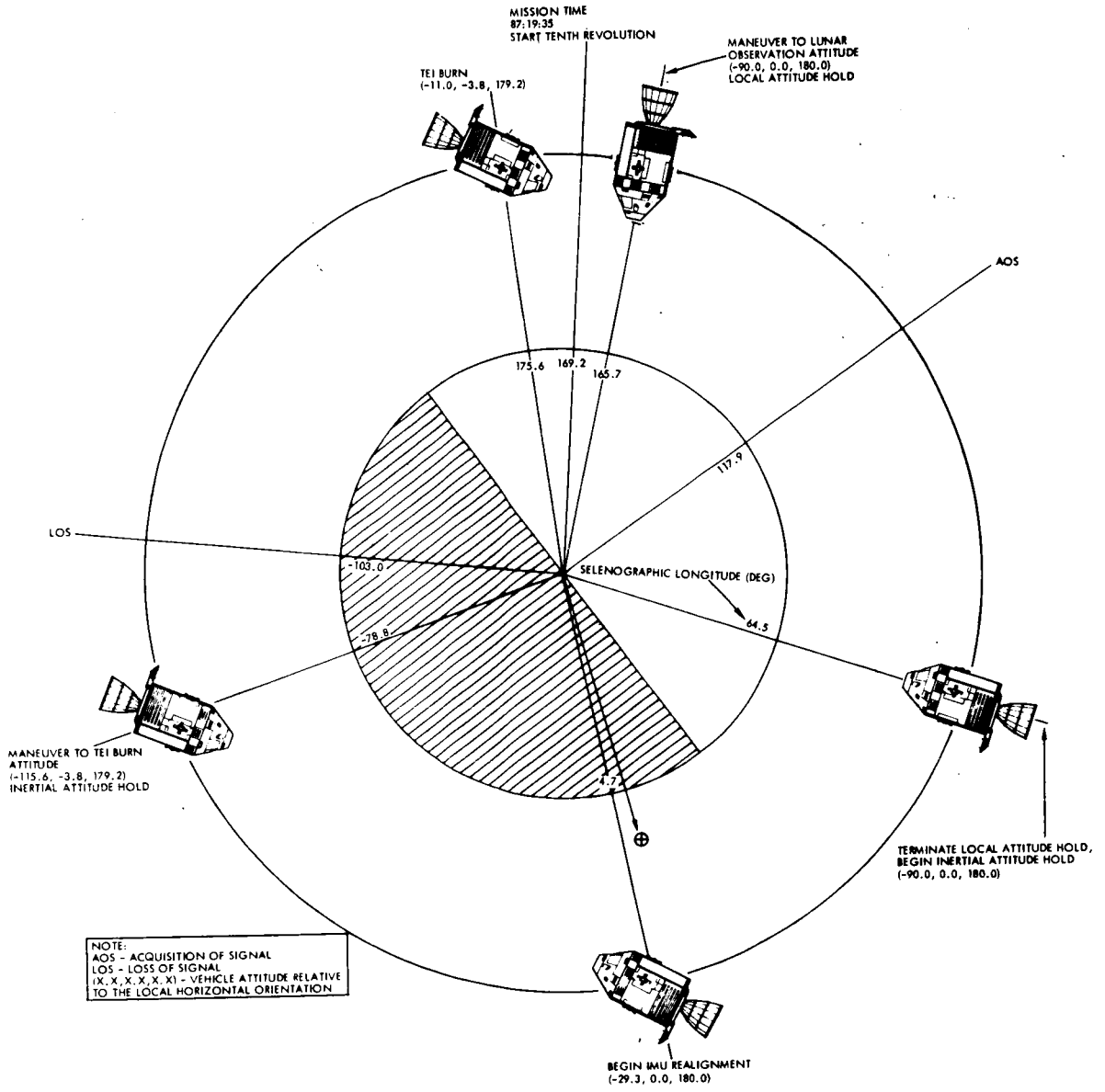


Figure 16. Tenth Revolution Major Events and Attitudes

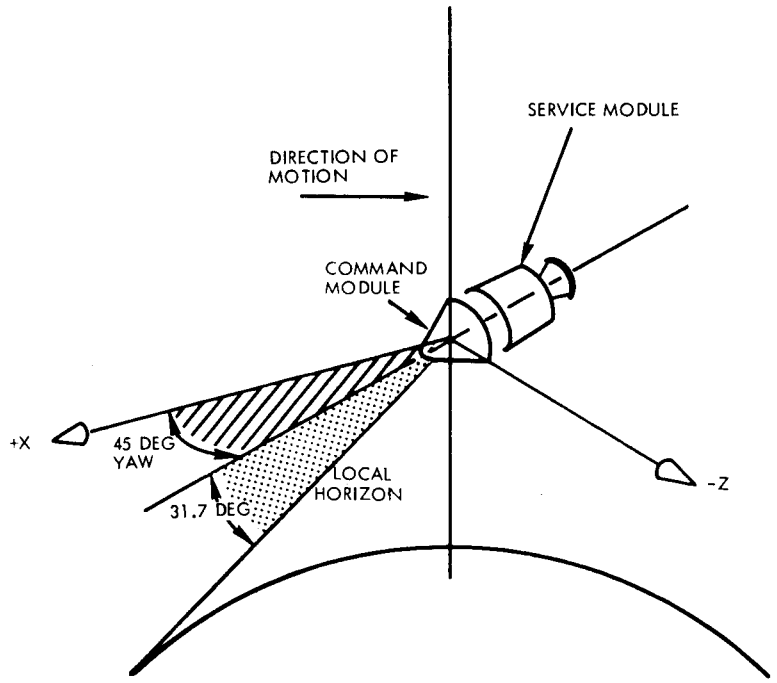


Figure 17a. CM/SM Separation Attitude

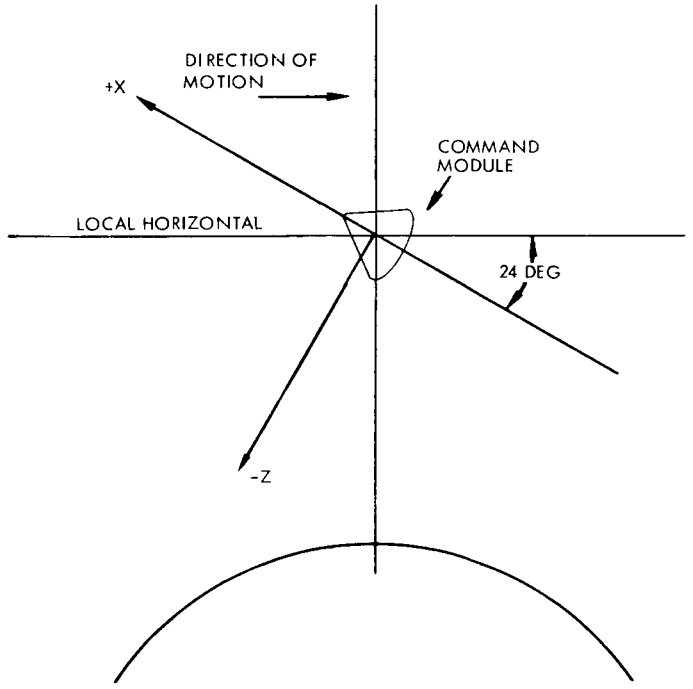


Figure 17b. CM Entry Attitude

REFERENCES

1. Attitude Sequence for the Apollo 8 Spacecraft Operational Trajectory. MSC Internal Note 68-FM-282, November 22, 1968.

2. Final Flight Plan Apollo 8. NASA MSC Document, November 22, 1968.

3. G. W. Ricks: C' Mission Post TLI Sequence of Events. MSC Memorandum 68-FM55-303, October 7, 1968.